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ART. LIII.—*The Forests of Central Nevada, with some remarks on those of the adjacent regions;* by CHARLES S. SARGENT.

To the traveler crossing the Great Basin by the line of the Pacific Railroad the country will appear almost as destitute of trees as the great plateau over which he has passed in approaching the Rocky Mountains from the east. This first impression will disappear, however, should he penetrate farther south, and ascend some of the low mountain ranges, which, with a general north-and-south trend, everywhere cut up this elevated interior region into long, narrow valleys. As compared with our Atlantic forests, or those still nobler ones which, farther to the west, owe their existence to the influence of the Pacific, the forests which clothe, with a scanty and stunted vegetation, the mountain slopes of Nevada are miserably poor in extent, productiveness, and especially in the number of species of which they are composed. Actually they are of immense value. For scanty as they are, they regulate and protect the rare and uncertain streams on which the agriculture of Nevada depends, and furnish a large population with fuel and lumber; a population, too, which, while consuming and wasting enormously its forests in vast mining operations, is practically cut off, by its isolation and the cost of transportation, from outside supply.

A hurried journey made in Septemper last, undertaken for the purpose of studying *in situ* the trees of the "Great Basin," and of introducing into cultivation some of the peculiar plants of that region, took me to the great mining center of Eureka, and then through Dry and Fish-spring valleys seventy-five miles further southwest into the Monitor Range, to the point

where its highest peak, "Table Mountain," reaches an elevation of 11,200 feet, and offered an excellent opportunity to examine the timber supply of that central portion of Nevada.

The forests of this portion of the State are composed of but seven species. Of these, two, the Red Cedar (*Juniperus Virginiana* L.) and the Aspen (*Populus tremuloides* Michx.) extend across the Continent; two, *Pinus Balfouriana* Murr. and *Pinus flexilis* James, extend along the mountain ranges from the Rocky Mts. of Colorado to Mt. Shasta in California; two, *Pinus monophylla* Torr. and *Juniperus Californica* Carrière, var. *Utahensis* Engelm. are endemic to the "Great Basin;" while *Cercocarpus ledifolius* Nutt., although occurring as a shrub both in the Rocky Mts. and in California, only here becomes a valuable tree.

Neither the Red Cedar nor the Aspen needs be considered here. A single small plant of the former was noticed; and it is evidently so rare throughout this region that it adds but little to the value of its forests. The Aspen borders all the mountain streams above 8,000 feet elevation, but, rarely surpassing fifteen feet in height and a few inches in diameter, is practically without value for its products. Further east in the Wahsatch Mts. this species is sometimes seen with stems two feet through; and it is largely used by the Mormons, who consider it valuable for flooring, turnery, etc.

Juniperus Californica, var. *Utahensis*, is the most common, and the most widely distributed of the trees of this region. It is found at lower elevations than any other tree, and alone descends into the valleys, where, at an elevation of 5,000 feet, it is often abundant, but less so than on the mountain sides, over which it spreads up to 8,000 feet elevation. It is a low, bushy tree, branching from the ground, with a stout trunk which rarely exceeds two feet in diameter; short and very stout branchlets, and thick shreddy bark. The wood, which is moderately hard, pale colored, and slightly aromatic, furnishes the common and cheapest fuel both for domestic use and for generating steam on the railroads and at the mines. The typical *Juniperus Californica* belongs to the California Coast Range, and the variety extends over the whole of the southern portion of the "Great Basin." In fruit this species will be readily distinguished by its dry one-seeded berry, the great thickness of the stony coating of the seeds; and from all other Junipers (as pointed out by Dr. Engelmann) by its 4–6-cotyledonous embryo. Without fruit it may be easily confounded with *Juniperus occidentalis* Hook., which species, however, has not been detected in Central Nevada. Like all the trees of the "Great Basin" this Juniper is of exceedingly slow growth. A specimen before me four and one-half inches in diameter shows

one hundred and five annual layers of growth, or an annual average increase of nearly $\frac{1}{5}\frac{1}{0}$ of an inch.

Growing with this Juniper, above 6,000 feet elevation, and extending rather higher up the mountains, is *Pinus monophylla* Torr., the "Nut Pine" of Nevada and eastern California; but not to be confounded with an allied species, also bearing edible seeds, *Pinus edulis* Engelm., found from Colorado to New Mexico and Arizona. *Pinus monophylla* is a small tree, ten to twenty feet high, with reddish scaly bark, and is easily distinguished from other North American Pines by its *solitary*, glaucous, terete leaves (very rarely in pairs, and then semi-cylindrical). The wood is white, soft, light, and very resinous; it is more highly prized for making charcoal than that of any tree of this region. In slowness of growth *Pinus monophylla* does not essentially differ from the Juniper with which it is associated; a specimen that I have examined, from the locality which furnished the specimen of Juniper referred to above, is five and one-half inches in diameter and shows one hundred and thirteen annual layers of growth. The immense crops of large and delicately flavored seeds produced by this tree supply, as is well known, to the Indian tribes of the Great Basin their most important article of food. The value of this crop, and the excellent quality of the wood for charcoal, make this tree, in a mining region entirely destitute of coal, its most valuable vegetable production. The introduction of *Pinus monophylla* into the South of Europe as a subject for forest planting is worthy of consideration; it might flourish there on those dry and exposed hill sides which have been found so difficult to satisfactorily recover with any European tree. Its strictly pyramidal habit while young—a habit which it entirely loses with age—and the pleasing glaucous tints of its foliage commend this species to the lovers of ornamental conifers.

*Pinus Balfouriana** was only met with on Prospect Mountain, near Eureka, at an elevation of 7,500 feet, to the summit, 8,000 feet. Formerly the whole summit of this mountain was very generally covered with this species, but with few exceptions the trees have all been cut to supply the mines with timbering, for which purpose the strong and very close-grained, tough wood of this species is preferred to that of any other Nevada tree. The specimens seen were fifteen to thirty feet high, with trunks often two feet in diameter, pyramidal in outline, their lower branches still remaining; so that at a little distance they might readily be mistaken for spruces. The bark like the wood is reddish in color, very thick and deeply furrowed; that

* With the insufficient material at my disposal I cannot satisfactorily separate *Pinus aristata* Engelmann, from Murray's *P. Balfouriana*, the older name and founded on California specimens. *Pinus aristata* is an alpine plant discovered by Parry many years later in the Rocky Mts. of Colorado.

of the branches smooth and quite white. The short, falcate, appressed leaves persist for years, forming tufts of foliage a foot or more long at the ends of the naked branches; and this peculiarity has suggested to the lumbermen of the region the name of "Fox Tail Pine" for this species. *Pinus Balfouriana*, should it be found to retain in cultivation the peculiarities which characterize it on the mountains of Nevada, will be one of the most striking and interesting of the genus for ornamental planting.

Pinus flexilis, the Nevada representative of the Eastern White and the California Sugar Pine, is the largest and the most valuable timber tree of the central portion of the "Great Basin." I found large tracts of it on the Monitor Range, from 8,000 up to 10,000 feet elevation; and further to the northeast it gives their names to "White Pine" District, "White Pine" Range, etc. On the Monitor Range specimens fifty to sixty feet high, and from two-feet six to four feet in diameter were not infrequent, the trees gradually becoming smaller as the elevation increased, until at 10,000 feet they were little more than prostrate bushes a foot or two high. The fact that the finest specimens were found on the banks of the mountain streams, associated with *Populus tremuloides*, indicates that this species is more dependant on moisture than the other Nevada Conifers. It is the only tree of this region which is sawed into lumber. The wood is soft, white, and, although not free from knots, is of fair quality, and about intermediate between Eastern white pine and sugar pine.

Cercocarpus ledifolius, with *Populus tremuloides*, the only non-coniferous tree of this region, here attains its largest size and greatest age. It is common at 6,000 to 8,000 feet elevation, and next to the Juniper and the Nut Pine is the most common of Central Nevada trees. It is a small tree, ten to thirty feet high, with small evergreen leaves and brown scaly bark, in habit and general appearance not unlike a stunted apple tree. The wood of this tree, which is of a bright mahogany color and susceptible of a beautiful polish, is exceedingly hard, heavy and close-grained, but very brittle, and so liable to "heart shake" and difficult to work as to be useless in the arts. It is, however, sometimes employed for the bearings of machinery, where it is found to wear as well as metal; but it is as fuel that "Mountain Mahogany" (the name by which, owing to the color of its wood, *Cercocarpus* is universally known) has no North American equal. We are in the habit of considering that our Eastern Hickories produce the best fuel. The specific gravity of dry hickory is but ·838, while that of *Cercocarpus* is 1·117, so that, weight being the best test, as fuel it is worth 30 per cent. more than hickory. The amount of ash, too, left after

burning *Cercocarpus* is only $\frac{5}{1000}$ of 1 per cent of the dry wood consumed, while that of hickory is $\frac{8}{1000}$ of 1 per cent, three-tenths per cent more. *Cercocarpus* is probably the only North American wood which is heavier than water; and among the tropical woods employed in the arts and described by Lastett, but six equal or surpass it, the most conspicuous being the West Indian Lignum Vitæ (*Guaicum*) with a specific gravity of 1·248. As was to be expected, the growth of *Cercocarpus* was found to be exceedingly slow. An examination of several specimens from one to two hundred years old shows an average annual increase of wood only one-sixtieth of an inch in thickness. The largest specimen of this tree was seen on Prospect Mountain near Eureka, in New York Cañon, at an elevation of 7,000 feet. It was a low, much branched tree, about twenty feet high with a trunk rising six feet to the first branches. At three feet from the ground it had a girth of seven feet and five inches. If we suppose that its average growth had been as rapid as that of the younger specimens examined, this tree would have been 890 years old. It was probably much older. The rate of growth of trees is, after a certain age, in inverse ratio to their age; and it is perhaps permissible to suppose that the seed which produced this little tree had already germinated when the oldest living *Sequoia* on the Continent was still a vigorous sapling with its bi-centennial anniversary still before it.

Two shrubby plants of this region may be mentioned, which, from their beauty, are especially worthy of introduction to cultivation,—*Cowania Mexicana* Don., a large Rosaceous shrub, nearly allied to *Cercocarpus*, with elegant pinnatifidly-lobed leaves and large and very abundant yellow flowers; and a large shrubby *Spiræa*, *S. Millefolium* Torr., with the foliage of *Chamæbatia*, but a larger and more striking plant, and perhaps the most elegant of the genus.

It will have been seen that the forests of Nevada, consisting of a few species adapted to struggle with adverse conditions of soil and climate, are of immense age, and that the dwarfed and scattered individuals which compose them reach maturity only after centuries of exceedingly slow growth. On this account, and because, if once destroyed, the want of moisture will forever prevent their restoration, either naturally or by the hand of man, public attention should be turned to the importance of preserving, before it is too late, some portions of these forests. Large areas of forest-covered mountain ranges are still held by the General Government; and in view of the vast importance of their remaining wooded to serve as reservoirs of moisture, on the existence of which the future of this region must depend, it would seem wise and not perhaps altogether impracticable, to check, or at least to regulate, the terrible destruction of

forest, which follows, both on public and private domain, every new discovery of the precious metals.

A comparison of the arborescent vegetation of Nevada with that of the region lying directly east and west of the "Great Basin" may be interesting. Such a comparison will serve to more clearly demonstrate the remarkable poverty of the Nevada forests. It will afford, too, another illustration of the relation of moisture to forest distribution, especially with reference to the multiplication of species, which will be found to increase or diminish as the rain-fall is more or less abundant and more or less equally distributed.

In the territory between the 41st and 37th parallels of latitude, and extending from the eastern base of the Rocky Mts. to the foot of the western slope of the Sierra Nevada are three distinct belts of arborescent vegetation.* Beginning at the east there is: 1. The Rocky Mountain Region including, besides the main range, the Uinta and the Wahsatch, and embracing Colorado and the eastern half of Utah; 2. The Nevada Region, extending from the western base of the Wahsatch, to the eastern base of the Sierra Nevada, and embracing the western half of Utah and the whole of Nevada with the exception of the extreme northern and southern portions of the State; 3. The Sierra Nevada Region.

In the Rocky Mountain Region, to which in spite of its mid-continental position considerable moisture is attracted by the high peaks which everywhere dominate it, there are twenty-five trees and forty-eight shrubs, in all seventy-three species. In the Nevada Region, where, owing to its isolated position between high mountain ranges, the rain-fall is small and very unequally distributed, the number of species is reduced nearly one-half,—to thirty-eight; ten trees and twenty-eight shrubs. In the Sierra Nevada Region, to which the Pacific contributes a large although unequally distributed, snow and rain fall, the number of species is increased to eighty-nine; of these thirty-five are trees,† or three and a half times more than occur in the adjoining Nevada Region, and a third more than are found in the Rocky Mountain Region; and fifty-four are shrubs, or double the number of the Nevada Region.

The following table shows the arborescent‡ and frutescent species, so far as they are now known, which occur in these three Regions.

* For the purpose of the present comparison not only trees but all frutescent plants which may be expected to exceed four feet in height, and therefore as undergrowth to form an important element in the forest, will be included.

† *Pinus monophylla* Torr., although it has found a foothold on the eastern flank of the Sierra Nevadas, is not included among the trees of this region. This species, as well as *Artemesia tridentata*, are so peculiar to the Nevada Region that they cannot be properly considered a part of the Flora of the Sierra Nevada.

‡ Species which become large enough to be of economic value as timber trees, are designated by a *.

The Rocky Mt. Region.	The Nevada Region.	The Sierra Nevada Region.
Berberis Fendleri.	*Berberis Fremontii.*	
		Calycanthus occidentalis.
		Fremontia Californica.
Ptelea angustifolia.		
Rhamnus Californica.		*Rhamnus Californica.*
		Rhamnus alnifolia.
		Rhamnus crocea.
		Ceanothus cordulatus.
		Ceanothus integerrimus.
		Æsculus Californica.
*Acer grandidentatum.**		*Acer macrophyllum.**
Acer glabrum.	*Acer glabrum.*	*Acer glabrum.*
Negundo aceroides.		
Rhus glabra.		
[*bata.*	[*bata.*	*Rhus diversiloba.* [*bata.*
Rhus aromatica, var. *trilo-*	*Rhus aromatica*, var. *trilo-*	*Rhus aromatica*, var. *trilo-*
Robinia Neo-Mexicana.		
		Cercis occidentalis.
Prunus Pennsylvanica.		*Prunus subcordata.*
Prunus Virginiana.	*Prunus Andersonii.*	*Prunus emarginata.*
Prunus demissa. [*mosa.*	*Prunus demissa.* [*mosa.*	*Prunus demissa.*
Spiræa discolor, var. *du-*	*Spiræa discolor*, var. *du-*	*Spiræa discolor*, var. *dumosa.*
	Spiræa Millefolium.	
Neillia opulifolia.		*Neillia opulifolia.*
Rubus deliciosus.		*Rubus Nutkanus.*
Purshia tridentata.	*Purshia tridentata.*	
Coleogyne ramossisima.		
Cercocarpus parvifolius.		*Cercocarpus parvifolius.**
*Cercocarpus ledifolius.**	*Cercocarpus ledifolius.**	*Cercocarpus ledifolius.*
Cercocarpus intricatus.		
Cowania Mexicana.	*Cowania Mexicana.*	
	[*tramontana.*	*Adenostoma fasciculatum.*
Rosa blanda.	*Rosa Californica*, var. *ul-*	*Rosa Californica.*
Rosa blanda, var.	*Rosa blanda*, var.	
		Heteromeles arbutifolia.
Pyrus sambucifolia.		*Pyrus sambucifolia.*
Cratægus rivularis?		*Cratægus rivularis.*
Cratægus coccinea.		
Amelanchier alnifolia.	*Amelanchier alnifolia.*	*Amelanchier alnifolia.*
Peraphyllum ramosissimum.		
Philadelphus microphyllus.		*Philadelphus Lewisii.*
Fendlera rupicola.		
		Carpenteria Californica.
Ribes cereum.	*Ribes cereum.*	*Ribes cereum.*
Ribes aureum.	*Ribes aureum.*	*Ribes aureum.*
Ribes leptanthum.		*Ribes leptanthum.*
Ribes bracteosum. [*guum.*		*Ribes Menziesii.*
Ribes divaricatum, var. *irri-*		*Ribes oxyacanthoides.*
		Ribes sanguineum, var. *va-*
		[*riegatum.*
Cornus pubescens.	*Cornus pubescens.*	*Cornus pubescens.*
		Cornus sessilis.
		Cornus Nuttallii.
		Garrya Fremontii.
Sambucus glauca.	*Sambucus glauca.*	*Sambucus glauca.*
Sambucus racemosa.		*Sambucus racemosa.*
Lonicera involucrata.	*Lonicera involucrata.*	*Lonicera involucrata.*
		Cephalanthus occidentalis.
Artemisia tridentata.	*Artemisia tridentata.*	
		Leucothæ Davisiæ.
		Arctostaphylos pungens, var.
		[*platyphylla.*
		Rhododendron occidentale.
		Styrax Californica.
	Fraxinus anomala.	*Fraxinus dipetala.*
		*Fraxinus Oregona.**
Forestiera Neo-Mexicana.		

The Rocky Mt. Region.	The Nevada Region.	The Sierra Nevada Region.
		Eriodictyon glutinosum.
		Umbellaria (*Oreodaphne*) *Californica.**
Shepherdia Canadensis.	*Shepherdia Canadensis.*	
Shepherdia argentea.	*Shepherdia argentea.*	
	Shepherdia rotundifolia.	
Elæagnus argentea.		
Sarcobatus vermiculatus.	*Sarcobatus vermiculatus.*	
Atriplex confertifolia.	*Atriplex confertifolia.*	
	Spirostachys occidentalis.	
Celtis occidentalis. [*mila.*		
Celtis occidentalis, var. *pu-*		
Quercus undulata.*		*Quercus lobata.** [*cosa.*
		Quercus lobata, var. *fruti-*
		*Quercus Douglasii.**
		*Quercus chrysolepis.**
		Quercus chrysolepis, var. *vaccinifolium.*
		*Quercus Sonomensis.**
		*Quercus Wislizeni.**
		*Quercus densiflora.**
		*Castanopsis chrysophylla.**
Betula occidentalis.		
Betula glandulosa.		[*fornica.*
Corylus rostrata.		*Corylus rostrata*, var. *Cali-*
		Myrica Hartwegi.
Alnus incana.		*Alnus incana.*
Alnus viridis.		*Alnus rhombifolia.*
Salix longifolia.	*Salix longifolia.*	*Salix*, species.
Salix cordata.	*Salix cordata.*	*Salix*, species.
Populus tremuloides.*	*Populus tremuloides.**	*Populus tremuloides.**
Populus angustifolia.*	*Populus angustifolia.**	*Populus Fremontii.**
Populus balsamifera, var. [*candicans.**	*Populus trichocarpa.**	*Populus trichocarpa.**
Ephedra trifurca.	*Ephedra trifurca.*	
Pinus contorta.* [*folia.**		*Pinus contorta.**
Pinus contorta, var. *lati-*		
Pinus ponderosa.*		*Pinus ponderosa.** [*freyi.**
		Pinus ponderosa, var. *Jef-*
Pinus edulis.*	*Pinus monophylla.**	
Pinus flexilis.*	*Pinus flexilis.**	*Pinus flexilis.**
Pinus Balfouriana.*	*Pinus Balfouriana.**	*Pinus Balfouriana.**
		*Pinus Sabiniana.**
		*Pinus tuberculata.**
		*Pinus monticola.**
		*Pinus Lambertiana.**
Picea Engelmanni.*	*Picea Engelmanni.**	
Picea pungens (*Abies Menziesii* of the Colorado Flora).*		
Abies subalpina.*		
Abies concolor.*		*Abies concolor.**
		*Abies magnifica.**
		*Abies nobilis.** [*liamsoni*)*
Pseudotsuga Douglasii.*		*Tsuga Hookeri* (*Abies Wil-*
		*Pseudotsuga Douglasii.**
		*Sequoia gigantea.**
		*Libocedrus decurrens.**
		*Taxus brevifolia.**
		*Torreya Californica.**
Juniperus occidentalis, var.*	[*Utahensis.**	*Juniperus occidentalis.**
	Juniperus Californica, var.	
Juniperus Virginiana.*	*Juniperus Virginiana.**	
73 species.	38 species.	89 species.
47 genera.	26 genera.	51 genera.
19 timber trees.	10 timber trees.	31 timber trees.
6 small trees.	28 shrubs.	4 small trees.
48 shrubs.		54 shrubs.

The following species, fourteen in number, are common to the three Regions:

Acer glabrum.
Rhus aromatica, var.
Prunus demissa.
Spiræa discolor, var.
Cercocarpus ledifolius.
Amelanchier alnifolia.
Ribes cereum.
Ribes aureum.
Cornus pubescens.
Sambucus glauca.
Lonicera involucrata.
Populus tremuloides.
Pinus flexilis.
Pinus Balfouriana.

The following species, twelve in number, are, in addition to those named above, common to the Rocky Mt. and Sierra Nevada Regions:

Rhamnus Californica.
Neillia opulifolia.
Cercocarpus parvifolius.
Pyrus sambucifolia.
Ribes leptanthum.
Sambucus racemosa.
Alnus incana.
Pinus contorta.
Pinus ponderosa.
Abies concolor.
Pseudotsuga Douglasii.
Juniperus occidentalis.

All the species of the Nevada Region extend into the Rocky Mt. Region with the exception of the following ten species:

Berberis Fremontii.
Prunus Andersonii.
Spiræa Millefolium.
Rosa Californica, var.
Fraxinus anomala.
Shepherdia rotundifolia.
Spirostachys occidentalis.
Populus trichocarpa.
Pinus monophylla.
Juniperus Californica, var.

Populus trichocarpa is the only species (with possibly the two willows) of the Nevada Region, which, in addition to the fourteen species common to the three Regions, extends into the Sierra Nevada. So that fifteen species of the Nevada Region reach the Sierra Nevada Region, while twenty-eight species extend into the Rocky Mountain Region, leaving but ten species peculiar to the Nevada Region. Of these *Fraxinus anomala* and *Shepherdia rotundifolia* are endemic; the other eight species extending south into Arizona.

The following genera common to the Sierra Nevada and Atlantic Forests, have no representatives in the mid-continental Flora:

Calycanthus.
Æsculus.
Cercis.
Cephalanthus.
Leucothoë.
Rhododendron.
Styrax.
Myrica.
Tsuga.
Torreya.

The following genera of the Sierra Nevada Region have no Eastern representatives:

Fremontia.
Adenostoma.
Heteromeles.
Carpenteria.
Garrya.
Eriodictyon.
Umbellaria.
Castanopsis.
Sequoia.
Libocedrus.

The absence of arborescent and frutescent *Leguminosæ* from the three Regions, where herbaceous genera of this order are so largely represented, is remarkable, especially as they abound

farther south in New Mexico and Arizona. In the Rocky Mt. Region there is a single representative of this order, a *Robinia* nearly allied to those of the Eastern States; in the Nevada Region there is not a single frutescent *Leguminosa*, and in the Sierra Nevada but one species, a large shrubby *Cercis*. On the contrary the number of genera of frutescent *Rosaceæ*, many of them endemic and monotypic, is very large in proportion to other *Angiospermæ*. In the Rocky Mt. Region there are thirteen genera with nineteen species; in the Nevada Region seven genera with ten species; in the Sierra Nevada Region eleven genera with thirteen species; in all, fourteen genera with twenty-eight species. In all the United States east of the Mississippi River there are but ten woody Rosaceous genera, all represented in our three Regions with the exception of the Southern *Chrysobalanus* and *Neviusia*.

The comparison of these three Regions with reference to the distribution of the oaks will show how dependent these are on moisture. Oaks abound in both the Atlantic and Pacific forests, while in the Rocky Mt. Region there is but a single, exceedingly polymorphous species, which does not reach the Nevada Region, where no oak is known; nor has this genus, so far as I know, any foot-hold on the dry eastern slope of the Sierra Nevada. A few insignificant species extend, however, along the mountains of Arizona and New Mexico, where the precipitation of moisture is more regularly distributed than farther north, and serve to connect the oaks of the Pacific with those of the Atlantic forests.

The absence of *Pinus ponderosa* from the Nevada Region is remarkable. This species abounds in all the Rocky Mt. Region, and extends through New Mexico and Arizona to the Sierra Nevada, where, on the dry eastern slope, it constitutes in some of its forms fully three-quarters of the forests. It might therefore be naturally looked for on some of the higher mountains of Central Nevada, where, however, it has not yet been seen.

Pseudotsuga Douglasii, which also abounds in the Rocky Mt. Region, and on the higher mountains of New Mexico and Arizona, does not enter the Nevada Region. This is less remarkable, perhaps, than the absence of *Pinus ponderosa*, as this tree does not appear, in any numbers at least, on the eastern slope of the Sierras, and only reaches its noblest development in the humid climate of the northwest coast.

Juniperus Virginiana, the most widely distributed of North American trees, ranges from the Saint Lawrence River to Florida, and from the Atlantic to the Northern Pacific. It does not, however, enter the Sierra Nevada Region, and is extremely rare in Nevada.

ART. LIV. — *On Ethylidenamine Silver Sulphate;* by W. G. MIXTER. Contributions from the Sheffield Laboratory of Yale College, No. LVI.

ALDEHYDE AMMONIA precipitates metallic silver from many of its salts almost as readily as from the nitrate. A mixture of solutions of silver sulphate and aldehyde ammonia produces a mirror when warmed, and at common temperatures evaporates to dryness, with but slight decomposition. The fact that a sulphate solution decomposed less readily than the nitrate led to the hope that an investigation of the sulphate compound would throw more light on the constitution of silver amines. The first experiments were made with ammoniacal aqueous solutions of silver sulphate and aldehyde ammonia. Analyses proved the crystalline product to be a mixture. Alcoholic ammonia was next used as a solvent, and the analysis of the first crop of crystals showed nearly pure $Ag_2SO_4(NH_3)_4$, 0·6 per cent of carbon was found and a solution of the crystals reacted for aldehyde. Aqueous solutions of silver sulphate and a large excess of aldehyde ammonia, over four molecules of the latter to one of the former, yielded either mixtures or ammonio silver sulphate. When, however, aldehyde ammonia is dissolved in a small quantity of water, and silver sulphate, in the proportion of one molecule of the latter to four molecules of the former, is slowly added with constant agitation; and after some hours the small black residue filtered off and the solution left to spontaneous evaporation, few or no crystals of the ammonio sulphate form, but colorless transparent crystals separate, which react strongly for aldehyde. At summer temperatures tabular crystals, and at from 10° to 15° C. elongated crystals, predominate.

The following analyses were made of carefully selected and well-defined tabular crystals, which were from 2 to 5^{mm} in diameter, and which were freed as much as possible from the mother liquor by blotting paper, then washed with alcohol and finally with ether. They were considered dry when they did not lose weight on the balance in five or ten minutes.

	Calculated for $Ag_2SO_4(C_2H_4NH)_4$	I.		II.		III.	Calculated for $Ag_2SO_4(C_2H_4NH)_2NH_3$	
S	6·61	6·68						
Ag	44·64	44·55	2	48·60	2	46·03	2	47·10
C	19·83	18·13	7·4	15·90	5·9	16·27	6·2	15·72
H	4·13	4·62		4·14		4·31		3·95
N	11·57	11·28						12·20
**	***	***	**	***	**	***	**	***
$3H_2O$	10·04	10·24		10·50		10·39		10·15

	Calculated for $Ag_2SO_4(C_2H_4NH)_2NH_3 3H_2O$	IV.		V.			
Ag	42·20	42·08	2	41·08	2	41·07	2
C	14·06	13·92	5·9	14·73	6·4	14·77	6·4
H	4·69	4·91		4·88			
N	10·90	10·64					
**	***	***	**	***	**	***	**
$3H_2O$	10·15				10·20		

The following results were obtained from crystals of an entirely different habit from those used in the preceding analyses, many of the crystals were one or two centimeters long, 4 or 5mm wide, and 1 to 3mm in thickness. They were freed from the mother liquor in the manner already described.

	Calculated for $Ag_2SO_4(C_2H_4NH)_4 6H_2O$	VI.		Calculated for $Ag_2SO_4(C_2H_4NH)_4$	VII.			
S	5·40	5·26	1					
Ag	36·48	36·12	2	44·64	44·70	2	43·89	2
C	16·21	15·66	7·8	19·83	18·72	7·6	18·79	7·6
H	5·41	5·6		4·13	4·43		4·52	
**	***	***	**	***	*****			
N	9·46	9·06	3·9					
$6H_2O$	18·24	17·29			17·67			

The atomic relations between the silver and carbon found are expressed by the figures following the percentages. The combustion for I was with lead chromate, and this carbon result may be too low, as subsequent duplicate combustions on another lot of crystals gave variations of 1 per cent of carbon. All the other combustions were made with oxygen, copper oxide, lead chromate and metallic copper. The silver in I and VI was weighed as chloride, and the other silver estimations were from weighing the residue left in the tray after the combustions, a method necessitated by the small quantity of material available. The duplicate VII shows the possibility of a mechanical loss. An error of 1 per cent in the silver found makes but a small difference in the atomic ratio between the silver and carbon, since the atomic weight of the former is high. The sulphur was precipitated as barium sulphate, and the nitrogen as ammonium platinic chloride, after separating the silver with hydrochloric acid. The water was determined by drying over oil of vitriol or caustic potash. A drop of sulphuric acid on a watch glass in the potash desiccator showed that there was a slight loss of ammonia on drying. The weights of substance for VI from one crop of crystals were made rapidly. 0·7395 gram was at once placed in the combustion tube whose anterior half was red hot; 0·438 gram was next put into water for the nitrogen estimation, and finally 0·533 gram of crystals, which

had become opaque white on edge, were dried to a constant weight for the water determination, and then used to find the sulphur content. The 17·67 per cent of water in VII was from drying 2·37 grams of crystals which had also become opaque while on edges.

Analysis VI corresponds with the theory, and the anhydrous material used in VII was from the same kind of crystals. The deficiency in the amount of carbon found may be ascribed either to impurities or a slight decomposition. I after losing water of crystallization, has essentially the same composition as VII. Both I and VI are hydrates of a compound analogous to ammonio silver sulphate, thus,

$$Ag_2SO_4(NH_3)_4$$
$$Ag_2SO_4(CH_3CH{=}NH)_4,\ 3H_2O$$
$$Ag_2SO_4(CH_3CH{=}NH)_4,\ 6H_2O$$

The name ethylidenamine silver sulphate is proposed for the present.

Analysis IV was made with hydrous crystals, and II with anhydrous substance from the same crop of crystals which were apparently of the same form as the crystals which gave results I. II and IV, give the formula,

$$Ag_2SO_4(CH_3CH{=}NH)_3NH_3,\ 3H_2O.$$

Leaving out the $3H_2O$ we see that the substance has the same composition as a mixture of 3 molecules of $Ag_2SO_4(C_2H_4NH)_4$ and one molecule $Ag_2SO_4(NH_3)_4$. But if we suppose it a mixture of $Ag_2SO_4(C_2H_4NH)_4$, $3H_2O$ and $Ag_2SO_4(NH_3)_4$ we find that the water is 8·1 per cent and does not accord with the water found, and the conclusion is that the substance analyzed was not a mixture, but a compound containing three ethyliden groups, and answering to the formula already given. III and V of two different crops of crystals appear to be mixtures of $Ag_2SO_4(C_2H_4NH)_4$, $3H_2O$ and $Ag_2SO_4(C_2H_4NH)_3NH_3$, $3H_2O$. Ethylidenamine silver sulphate is soluble in water and yields aldehyde when treated with acids. The hexhydrated salt loses water more readily in dry air than the trihydrated.

ART. LV.—*Notes on the Satellites of Saturn;* by MARIA MITCHELL.

THE object glass of the telescope used in the observations which follow is of twelve and one-third inches diameter. Its definition is good.

The telescope is used in such observations as its very imperfect mechanism will allow; these are observations of the conjunctions of the satellites with the edge of Saturn's ring, of size and color, and of differences of right ascension.

The last are made by connecting with the chronograph, and recording the time of passage of the satellites over a fixed wire.

In the course of these observations such different relative magnitudes have been given to the small satellites, on different evenings, as to lead to the suspicion that some of them are variable.

The sparkle of Tethys and the grayish blue color of Rhea make it seem unlikely that small stars can have been taken for these two satellites; in the case of Enceladus and Dione mistakes are more easily made; but the rapid motion of Enceladus soon establishes its identity. The most noticeable changes are in Rhea.

In 1877, Rhea is recorded as small on Nov. 30th; as dull on Dec. 3d; as blurry and large, Dec. 14th; and as ruddy, Dec. 18th. In 1878 Rhea is recorded as faint Oct. 3d and Oct. 16th; as bright on Oct. 25th, and on Dec. 3d it is called nearly as bright as Titan.

1877, Oct. 5.—Rhea was in conjunction with the preceding edge of the ring at $8^h\ 58^m\ 29^s$ P. M. Two small satellites following the planet were in conjunction at the same time; the smaller one moved rapidly toward the ball.

1877, Oct. 6.—Two small satellites were nearly in conjunction with the edge of the preceding ring at $9^h\ 28^m$ P. M. The smaller of these was probably Dione; the larger may have been a star.

1877, Oct. 9.—$10^h\ 8^m$ P. M. Tethys is moving away from the ball and has passed conjunction with the ring. Another satellite, probably Enceladus, is coming in, and is nearly up to conjunction with the following edge of the ring.

1877, Oct. 13.—At 10 P. M., two small satellites were seen to be nearly together following Saturn, the space between them being $1''{\cdot}5$. At $10^h\ 53^m\ 31^s$, the two satellites could not be separated with a power of 400. The two were of the same size. At $11^h\ 20^m\ 31^s$, the satellites could be seen separated. These may be Tethys near greatest elongation, and Enceladus approaching the planet.

1877, Oct. 14.—Rhea was in conjunction with the preceding edge of the ring and above the ring at $9^h\ 9^m\ 30^s$.

1877, Oct. 23.—Rhea was again in conjunction with the preceding edge of the ring and above it, at $10^h\ 29^m\ 22^s$.

1877, Nov. 6.—Tethys was in conjunction with the preceding edge of the ring at $9^h\ 31^m\ 30^s$.

1877, Nov. 7.—Tethys was in conjunction with the following edge of the ring and above the ring at $9^h\ 22^m\ 50^s$.

1877, Nov. 13.—Dione was in conjunction with the following edge of the ring at $8^h\ 44^m\ 6^s$.

1877, Nov. 14.—Titan was in conjunction with the preceding edge of the ring at $8^h\ 7^m\ 6^s$.

1877, Nov. 16.—Enceladus was in conjunction with the following edge of ring and beneath it at $9^h\ 51^m\ 6^s$.

1877, Nov. 17.—The seeing was excellent. Two satellites, probably Tethys and Enceladus, were seen as one at $6^h\ 29^m\ 24^s$. In twenty minutes they had separated 3″. Rhea was in conjunction with the following edge of ring at $6^h\ 45^m\ 21^s$ and 3″ below the ring. Dione was nearly at conjunction with the preceding edge of ring at 7 P. M.

1877, Nov. 30.—Titan was in conjunction with the preceding edge of the ring at $7^h\ 17^m\ 1^s$. A small satellite (Tethys?) a little past conjunction and above the ring at $8^h\ 10^m$.

1877, Dec. 12.—Tethys was in conjunction with the preceding edge of the ring and below it at $6^h\ 48^m\ 49^s$.

1877, Dec. 14.—A small satellite preceded the ring by one and three-fifths the measurement of the preceding ansa. Was this Mimas? The time was $7^h\ 34^m$.

1877, Dec. 16.—Titan was in conjunction with the preceding edge of the ring at $6^h\ 19^m\ 36^s$.

1878, Jan. 12.—$5^h\ 50^m$ to 6 P. M. The ring of Saturn appeared as a line. Titan preceded the planet and three small satellites followed, two of them estimated to be a second of arc only asunder. The distance from the following edge of the ring to the two satellites so closely together was nearly twice that from the ball to the edge of the ring.

1878, Jan. 16.—Observations began at $4^h\ 50^m$ P. M. The ring was seen as a line at $5^h\ 12^m$, its following portion being seen first. A bright spot was seen on this portion of the ring.

1878, Jan. 18.—The night was very fine, and at 6 P. M. the ring could be seen as a ring. The preceding portion of the ring was sharper than that following. On the following portion a bright spot was seen.

1878, Jan. 29.—At $5^h\ 25^m$ P. M. the ring could be seen as a bright line across the planet. Titan preceded the planet and four satellites followed. At $6^h\ 40^m$ a very faint satellite was seen (Tethys?) nearly up to conjunction with the ring and moving toward the ball.

1878, Feb. 7.—$6^h\ 30^m$ P. M. Points of light could be seen preceding Saturn, but the continuity of the ring could not be kept. A small point of light, possibly a satellite preceded the ring. Rhea and Titan followed the planet.

1878, Oct. 3.—$8^h\ 40^m$ P. M. Two satellites, supposed to be Rhea and Dione, are nearly in conjunction and preceding the planet. Two others follow, Tethys moving out and Enceladus (?) nearly

at conjunction with the ring. Of the four satellites, Tethys is the brightest.

1878, Oct. 16.—Titan was in conjunction with the edge of the following ring at $7^h\ 38^m$; above the ring.

1878, Oct. 24.—Titan was seen emerging from the ball of Saturn at $9^h\ 16^m\ 30^s$. 7^h P. M.—A very faint satellite was seen by glimpses, following, nearly in conjunction with the ring.

1878, Oct. 25, 7 P. M.—Titan and another satellite supposed to be Rhea were nearly in conjunction separated by 7″. A very small satellite precedes the tip of the ring.

1878, Oct. 28.—Tethys was in conjunction with the edge of the following ring and below at $7^h\ 37^m$ P. M.

1878, Oct. 29.—Tethys was nearly at conjunction with the preceding ring and above at 7 P. M.

1878, Nov. 9.—At $8^h\ 18^m\ 3^s$ Titan was seen to emerge from the planet. It was wholly detached from the planet in twenty minutes. At $9^h\ 25^m$ P. M., a small satellite was seen, nearly at conjunction with the following ring.

1878, Nov. 13.—Six small bodies preceded Saturn. Of these, Titan, Rhea, Tethys and Dione could be identified. At $7^h\ 48^m$ P. M. the satellite supposed to be Rhea is distant from the preceding ring 6″, Tethys is distant 1″.

1878, Nov. 14.—$7^h\ 30^m$ P. M. A very small satellite follows Saturn, distant about 3″.

1878, Nov. 26.—Titan and a satellite supposed to be Rhea were asunder 6″ 3′ at $7^h\ 22^m$. If this satellite was Rhea, it was unusually bright. Tethys and a very faint satellite precede Saturn, the latter is probably Enceladus.

1878, Nov. 29.—At $6^h\ 15^m$ P. M. a small satellite preceded Saturn and three others followed. Of those following, that which was nearest to Saturn could not be found at 9 P. M., and the second in distance from Saturn had moved in; the latter was probably Tethys.

1878, Dec. 3.—Dione was in conjunction with the following edge and above the ring at $7^h\ 46^m\ 34^s$ P. M. A small satellite was seen by glimpses, following at a distance of 6″ from the ring.

1878, Dec. 6.—At $6^h\ 25^m$ a small satellite followed Saturn distant 7″ from the edge of the ring. This satellite could not be found at $7^h\ 55^m$ although the seeing was much better. At $7^h\ 55^m$ a small satellite having the peculiar sparkle of Tethys, was seen a little beyond the following edge of the ring, and moving away from the ball.

1878, Dec. 13.—Titan and three small satellites precede the planet, probably Rhea, Tethys and Dione. Of the three, Tethys is the brightest at $6^h\ 57^m$. It moves away from the ball. At $8^h\ 57^m$ two of these satellites could not be separated with a power of 230. I suppose them to be Tethys and Rhea.

1878, Dec. 16.—$9^h\ 5^m$ P. M. Tethys was nearly up to conjunction with the ring; moving toward the ball. Rhea was large and dull in color.

Observatory of Vassar College,
Longitude from Greenwich, $4^h\ 55^m\ 33{\cdot}9^s$.

ART. LVI.—*On the Force of Effective Molecular Action;* by Professor W. A. NORTON.

[Continued from page 358.]

FOR the critical curve the molecular repulsion has very nearly the constant value, $0{\cdot}0052\frac{m}{r^3}$, from $x=3r$ to $x=7{\cdot}5r$; and according to Dr. Andrews, the pressure of condensation at the critical point for carbonic acid gas was seventy-five atmospheres. These data give for the molecular repulsion answering to one atmosphere, $\frac{0{\cdot}0052\frac{m}{r^3}}{75}=0{\cdot}0000693\frac{m}{r^3}$. This should then be the value of the minimum repulsive ordinate, that obtains when $x=3r$, in the curve for water at the point of ebullition (212° F.). This result gives for this curve $k=4{\cdot}931$. In this curve the same molecular repulsion occurs again at $x=115r$. Now taking 1581 for the ratio of expansion by volume of water converted into steam at 212° F., and for the distance between the effective molecules of the steam, $115r$, and putting $y=$ distance of the inner surface of the effective envelope from the center of the molecule, I have

$$\frac{115r+2r+2y}{3r+2r+2y}=\sqrt[3]{1581};$$

which gives $y=2{\cdot}76r$. This calculation proceeds on the supposition that the effective molecules have the same size in the vaporous as in the liquid state, but theoretically they should be larger; and we shall see in the sequel that the probable value of the diameter of the molecules of steam is $42{\cdot}25r$. If we adopt this estimate, the ratio of expansion by volume, 1581 to 1, gives for the diameter of the liquid molecule at 212° F., $10{\cdot}5r$.

Let us now see how far the well known laws of gases may be deduced from our molecular formula.

(1). *Avogadro's Law*, relative to the simple gases; that all simple gases contain in the same volume, at the same pressure and temperature, the same number of ultimate molecules. This law follows from the fact that for the large distances between contiguous molecules, that obtain in gases, the effective repulsion is very nearly the same at the same distance for all the values of k that can answer to the different gases; together with the large size of the effective gaseous molecules. The entire possible range of value for k, for gases and vapors, is from 0 to 4·934; since it is only between these limits that the effective molecular force is repulsive at all distances. We

have already seen that when $k=4{\cdot}931$, and $x=115r$, the effective repulsion is $0{\cdot}0000693p$; and that this answers to one atmosphere of external pressure. When $k=0$ and $x=115r$, the effective repulsion is $0{\cdot}00007561p$; and the distance x at which the repulsion becomes $0{\cdot}0000693p$ is $120r$. But the distances between the centers of the molecules must be much greater than these values of x. It will soon appear that the law of Mariotte requires that the radius of the effective gaseous molecule, under a pressure of one atmosphere, be not less than $31r$. This gives for the distance between the centers of the molecules, under this pressure, $177r$ when $k=4{\cdot}931$; and $182r$ when $k=0$. Now $\left(\frac{182}{177}\right)^3=1{\cdot}086$. This is the highest ratio of volumes of two simple gases, under atmospheric pressure, that would be theoretically possible; unless the effective size of the molecules be supposed to diminish as k increases. But this is only an ideal extreme result. It will appear in the sequel that the values of k for the simple gases, oxygen, hydrogen and nitrogen, for which Avogadro's law, for a constant pressure and temperature, has been experimentally established, are included within narrow limits (probably 2 and 3). It thus becomes apparent that the extreme ratio of the number of molecules in the same volume cannot exceed 1·013, and may be much less.

(2.) *Avogadro's Law*, relative to compound gases; that the same volumes of these gases contain the same number of molecules, and the same number as equal volumes of the simple gases. The ordinary physical conception is that compound molecules are formed by the union of simple molecules, or of a certain number of their constituent atoms, and that these occupy the same volume that the simple molecules did. In some instances of chemical combination it necessitates the supposition that the formation of each new compound molecule is a result of the breaking up of several molecules of the combining substances. It also involves the improbable hypothesis that the space physically occupied by a molecule is wholly independent of the number of its constituent atoms. Upon the conception of variable ultimate molecules adopted in this and my previous paper, Avogadro's law simply implies that in the act of combination the effective molecules suffer a certain diminution of size, by the collapse of their envelopes. The same number of atoms may thus physically occupy the same volume as if they were closely to unite and form a compound molecule, upon the ordinary hypothesis. Thus in the formation of aqueous vapor by the combination of two volumes of hydrogen with one volume of oxygen, forming two volumes of the compound, a condensation of the individual molecules would take place, and as the result two ultimate

molecules of hydrogen and one of oxygen would occupy the same volume that three molecules of either gas did before the combination. It is to be observed, in confirmation of this view of the process of combination, that the reduction in the size of the effective molecules, would be attended with an increase in the ratio k, and a consequent increase in the value of the attractive term in equation (1), for the same value of x (or graphically, a rise of the curve of effective molecular action; see fig. 3).

The compound should therefore be a more condensable gas, or vapor. We have already obtained for aqueous vapor, at 212° F., $k=4{\cdot}931$; and it will appear hereafter that for oxygen, hydrogen, or nitrogen, the value of k must fall below 4, and is probably near 2. To obtain the theoretical size of the effective molecules of aqueous vapor, we have the equation $\frac{118r+62r}{115r+y'}=\sqrt[3]{\frac{3}{2}}$. This gives $y'=42{\cdot}25r$, and radius of molecule$=21{\cdot}12r$. The distance between the centers of contiguous molecules will be $157{\cdot}25r$. In this equation $118r$ is the distance between contiguous molecules of oxygen or hydrogen before condensation, and answers to $k=2$, nearly; and $62r$ is the diameter of one of the molecules (see page 436): $115r$ is the distance between the same molecules after the condensation into aqueous vapor; when k has been increased to $4{\cdot}931$.

In all combinations of simple gases the degree of condensation that occurs is expressed by the ratio of the number of atoms in the "compound molecule," as shown by the ordinary molecular formula, to 2, the assumed number of the constituent atoms of "the molecule" of a simple gas. In this statement it is supposed that the constituent gases before combination are in the perfect gaseous condition, like oxygen, or hydrogen, and that the compound gas has the temperature at which it is in a similar condition; so far as these two suppositions are implied in Avogadro's law.

Mariotte's, or Boyle's Law, of the uniform compressibility, by volume, of gases under increasing pressure. Upon the present theory this law should obtain if the effective molecular repulsion be inversely proportional to the volume occupied by the same number of molecules, or to the cube of the distance between the centers of contiguous molecules. For each molecule would then be the center of a system of recurring impulses propagated in waves by the interstitial luminiferous ether, proportional in intensity to the number (n) of molecules in a unit of volume, and every line radiating from any point of the enclosure into the body of gas would sensibly intersect a molecule at a greater or less distance. To obtain the entire impulsive action (P) on the point considered, we have then only to conceive a hemisphere traced around this point, and that all the points of

its surface are centers of radiating impulses proportional in intensity to n, and propagated according to the law of inverse squares. P should then be proportional to the intensity of the radiation at the points of the hemisphere, and therefore to n.

Now the expression for the effective molecular repulsion (equ. 1) consists of two terms of which the first, or attractive term, becomes relatively very small at the molecular distances that obtain, at moderate pressures, in gases (p. 346). The repulsive term, $\frac{m}{x^2}$, gives, then, very nearly the effective force, at such pressures; and more nearly in proportion as the ratio $\frac{n}{m}$ is smaller. Mariotte's law should then be satisfied, for considerable variations of pressure if the term $\frac{m}{x^2}$ should vary inversely as the cube of the distance (x') between the centers of contiguous molecules; that is, if $\frac{1}{x^2} \div \frac{1}{x'^3}$. If we denote by h the radius of the effective molecule, $x' = x + 2h$. As we are not in a position to determine à priori the law of variation of the size of the molecule under varying pressures, the only alternative is to adopt the hypothesis that $\frac{1}{x^2} \div \frac{1}{x'^3}$, deduce a series of values of the diameter $2h$, of the effective molecule that shall be in conformity with this hypothesis, and then test the results and hypothesis by deducing the theoretical deviations from the law of Mariotte in special cases, and comparing them with the deviations experimentally determined. Now I find that the hypothesis that $\frac{1}{x^2} \div \frac{1}{x'^3}$ is satisfied by the following values of $2h$, viz: 62·10, 62·00, 61·26, 60·32, 58·96, 57·12, 54·70, 51·58, 47·54, 42·24, 35·14, 30·53, 24·74, 16·89, 12·57,—answering respectively to the following values of u (equ. 2): 120, 115, 100, 90, 80, 70, 60, 50, 40, 30, 20, 15, 10, 5, and 3. Theoretically one gas differs from another in the value of k, and the larger this ratio the greater should be the deviations from the law of Mariotte, which strictly is fulfilled only when $k=0$, and so the attractive term in our formula equal to zero. These deviations should also increase as the pressure increases, since the attractive term will become relatively greater. The more permanent simple gases (oxygen, hydrogen, etc.), for which the law of Mariotte holds good over the greatest range of pressure, should then have the smallest values of the ratio k; and compound gases the larger values (see p. 435). We may now assume, as a basis for an approximate calculation, that the molecules of all the gases have equal diameters under equal

pressures, and we may then compute for any supposed value of k the volume that should obtain under any supposed pressure, and compare it with the value that would result if the law of Mariotte were strictly fulfilled. Dr. Andrews, in his Bakerian Lecture on the continuity of the gaseous and liquid states of matter, states that under a pressure of forty-nine atmospheres, at the temperature 13°·09 C.; the volume of carbonic acid gas was "about $\frac{3}{4}$ of the volume that Mariotte's law would give." The critical temperature of the gas he found to be 30°·92 C., and we have seen (p. 357) that for the critical curve $k=4·7$. This gives for the temperature 13°·09 C. $k=4·75$ (very nearly). Now calculating the volume for this value of k, and under a pressure of 49 atmospheres, I obtain 0·648 of the volume (V) Mariotte's law would give. Experiment gave 0·60V. By what has already been stated (p. 434), the actual diameter of a molecule of carbon-dioxide, under the pressure of one atmosphere, should be less than $62r$, the diameter assumed for molecules of oxygen and hydrogen. Taking it $52r$, I have deduced from the hypothesis that $\frac{1}{x^2} \div \frac{1}{x'^3}$ another series of values of the diameter $2h$; and making a new calculation, I find the theoretical volume =0·613V. The ratio of condensation from the perfect gas in the production of carbon dioxide (see p. 435) would lead us to conclude that the diameter of the molecule, at the temperature 13°·09 C. would be less than 50 (possibly as low as 40). Taking it at 40 I obtain by estimation the theoretical volume =0·58V. I have made other similar test calculations, with the aid of Dr. Andrews' experimental determinations with similar results.

Gay Lussac's Law of the uniform variation of the volume of a gas under constant pressure, as well as of the elastic force under a constant volume, resulting from a change of temperature. This may be deduced from the principle which gives Mariotte's law, that the molecular repulsion varies inversely as the volume, and the principle that it is directly proportional to the coefficient of repulsion (m), which must be proportional to the absolute temperature. We have already seen that the elastic pressure of a gas should be proportional to the molecular repulsion (F). Now for the range of pressure for which the law of Mariotte holds good, we have

$$\mathrm{F}=f=\frac{m}{x^2}=\frac{m'}{x'^3}=\frac{\mathrm{C}m}{x'^3}.$$

The volume is represented by x'^3. If x' becomes $x'+dx'$, the volume becomes $(x'+dx')^3=x'^3+3x'^2dx'$ (very nearly). Thus the increase of volume is $3x'^2dx'$; and the ratio of increase $\frac{3x'^2dx'}{x'^3}$. But the increment dx' is due to an increase of tem-

perature, and must answer to dm, while f remains constant. Thus $dx'=\frac{dm'}{3fx'^2}$, and therefore the ratio becomes

$$\frac{dm'}{fx'^3}=\frac{dm'}{m'}=\frac{dm}{m}.$$

For the case in which the volume is constant, while the temperature rises,

$$df=\frac{dm'}{x'^3}\text{; and }\frac{df}{f}=\frac{dm'}{fx'^3}=\frac{dm'}{m'}=\frac{dm}{m}.$$

Thus the ratio of the increase of volume is equal to the ratio of the increase of elastic pressure. We may assume that from a certain absolute temperature, T, m increases uniformly for each increment, 1° of temperature. Let t denote the actual temperature above T; then $m=c't$, and $\frac{dm}{m}=\frac{dt}{t}$. From which it appears that above T the increase of volume, or of the elastic pressure, takes place uniformly; that is, is equal in amount for equal increments of temperature. We may conclude from this investigation that Gay Lussac's law holds good only for that range of pressure and temperature within which the law of Mariotte is fulfilled; and that it is not strictly true for the more compressible gases and vapors, except at temperatures considerably above the point of condensation.

Specific Heat of Gases.—When the temperature of a gas is raised 1°, without change of volume, the heat is expended in exalting the vibratory state (i. e. the dynamic energy) of the molecular envelopes, and in augmenting their potential energy by expansion. It is obvious, then, that the specific heat of a gas, under a constant volume, should be some function of the ratio, k, since upon this must depend at a given temperature, the number of molecules in the unit of volume, and the mechanical condition of each molecule. The theoretical indications are that the specific heat of different gases, for the unit of volume, is directly proportional to the value of k; but as these cannot be adequately presented here we will assume this as an hypothesis and test it by the quantitative results to which it leads. To state the hypothesis with more precision, it is that the specific heat of a gas, when the volume is constant and the *initial* elastic pressure is one atmosphere, is, for a unit of volume, proportional to the value of k—it being understood that in the case of a compound gas the value of k considered is that which which obtains when the molecules are in the condition that immediately results from the formation of the gas from its constituents, and at the temperature at which the ratio of condensation is that proper to the gas.

When a gas is allowed to expand under a constant pressure, an additional amount of heat is expended in the work of this expansion in opposition to the external pressure. Now if n were equal to m the amount of heat thus expended should equal that which would be expended on the molecular envelopes. Let U denote the entire amount of heat expended when the pressure is constant, u that expended in the work of expansion, and u' that expended on the molecules directly; and we have $U=u+u'=u+su$. Each term is a function of the temperature, t; and, differentiating, we have $dU=du+sdu$. But we have seen that du equals the value which sdu would have if k, or $\frac{n}{m}$, were equal to unity. Denote it by e, and we obtain $dU=e+se$. But, since the specific heat under a constant volume is proportional to k, $\frac{se}{e}=\frac{k}{1}$; and thus $s=k$. This value of s gives $dU=(1+k)e$, and $sdu=ke$; from which $\frac{dU}{sdu}=\frac{1+k}{k}$. This is ratio of the specific heat under a constant pressure to the specific heat under a constant volume.

Let us now subject these theoretical results to the test of calculation. According to Pouillet the specific heat of aqueous vapor, under a constant volume, is 1·9600, and that of a mixture of one volume of oxygen and two volumes of hydrogen, 0·9277. The ratio of these is 2·113. For aqueous vapor we have seen that $k=4·93$. Thus, $\frac{4·93}{2·113}$ $(=2\frac{1}{3})$ should be the value of k for the mixture of oxygen and hydrogen before condensation into aqueous vapor. This result, as will appear in the sequel, is in accordance with the results of Professor Pictet's experiments on the liquefaction of oxygen and hydrogen.

Taking the specific heat of carbon-dioxide, under a constant volume at 1·26, we have $\frac{1·26}{0·9277}=1·36$, and $1·36\times 2\frac{1}{3}=3·17$. This is the value of k for this gas under a pressure of one atmosphere, and in the condition in which it exists as the immediate product of the combustion of carbon. It is here tacitly supposed, in accordance with fact, that the specific heat of the gas, for equal volumes, and under the pressure of one atmosphere, is the same, when in the state of a vapor, at whatever temperature it is supposed to be formed from a liquid. Theoretically there should be a tendency to this state of things, since when the temperature is higher the number of molecules in the unit of volume, at the same elastic tension, is less, but at the same time the specific heat of each molecule should be greater, owing to the increased size of its envelope, and its

consequent greater liability to expansion under the operation of the heat energy. For olefiant gas we have $\frac{1{\cdot}553}{0{\cdot}9277} = 1{\cdot}674$; and $1{\cdot}674 \times 2\frac{1}{3} = 4{\cdot}2$, the theoretical value of k for this gas. These results enable us to test our expression for the ratio of the specific heats under a constant volume, and at a constant pressure, viz: $\frac{1+k}{k}$. For the mixture of oxygen and hydrogen $\frac{1+k}{k} = \frac{1+2\frac{1}{3}}{2\frac{1}{3}} = 1{\cdot}430$. The experimental value is 1·410. For carbon-dioxide $\frac{1+k}{k} = \frac{3{\cdot}17+1}{3{\cdot}17} = 1{\cdot}315$. According to experiment it is 1·338. For olefiant gas the ratio is $\frac{4{\cdot}2+1}{4{\cdot}2} = 1{\cdot}24$, the same as obtained by experiment. For oxide of carbon I get $k = 2{\cdot}60$ and ratio of specific heats $= 1{\cdot}38$; experiment gives 1·428. For oxide of nitrogen $k = 3{\cdot}396$ and ratio of specific heats $= 1{\cdot}294$; experiment gives 1·343.

Professor J. Clerk Maxwell (Nature, March 10, 1875, p. 375) admits that the kinetic theory of gases has encountered a serious dilemma in the attempt to determine specific heats. He says, "We learn from the spectroscope that a molecule can execute vibrations of constant period. It cannot therefore be a mere material point, but a system capable of changing its form. Such a system cannot have less than six variables. . . . But the spectroscope tells us that some molecules can execute a great many different kinds of vibrations. They must therefore be systems of a very considerable degree of complexity, having far more than six variables;" and "every additional variable increases the specific heat, whether reckoned at constant pressure or at constant volume. But the calculated specific heat is already too great when we suppose the molecule to consist of two atoms only." The present theory encounters no such difficulty, since it regards the heat and light vibrations as pertaining to the atoms of the molecular envelopes, and the number of these is indefinitely great, and the determination of the specific heat requires no hypothesis of a definite number of atoms to be made. In the same connection Professor Maxwell has the following remark: "And here we are brought face to face with the greatest difficulty which the molecular theory has yet encountered, namely, the interpretation of $n+e=4{\cdot}9$. He had previously remarked "that $n+e$, for air and several other gases, cannot be more than 4·9. For carbonic acid (?) and steam it is greater." Now $n+e$ answers to the ratio, k, on the present theory, and we have seen (p. 433) that this is 4·93 for steam, and less than 4·9 for the gases.

Diffusion of Gases.—The law of variation of the molecular repulsion, at the distances between gaseous molecules, given by equ. (1), leads to the result that if one layer of such molecules moves over another, so that those on one side of the plane of separation are opposite the vacant spaces between those on the other side, a force of effective repulsion directed toward this plane will supervene, which will operate to diffuse each set of molecules into the volume occupied by the other. Did space admit, we might show that when all the circumstances of the case, and the resistances in operation, are duly considered, the diffusion thus originating should conform to the known laws of diffusion; as that the velocity of diffusion of the individual molecules is inversely proportional to the square root of the molecular weights, &c. The force of diffusion of liquid molecules has a similar origin. Upon this view the force of diffusion is incidental to the inevitable internal agitations occurring in fluid masses; and may be brought into more lively action by artificial disturbances. The molecular repulsive or heat energy consumed in such effects is restored to the mass by the subsidence of the individual movements, perpetually recurring.

Comparison of the present with the kinetic theory of gases.—The theory of gases which has now been deduced from the general expression for the force of effective molecular action (equa. 1, or 2), is no less dynamical in its essential character than the kinetic theory. The dynamical system conceived to be in operation is, upon the one view, the translatory wave movements and atomic vibrations of the interstitial ether and ethereal atmospheres of the molecules, and upon the other, the movements of translation of the molecules themselves, and the vibrations of their constituent atoms. The doctrine of Energy, and the principles of the Mechanical Theory of Heat, are as applicable to the one as to the other theory. The essential correspondence of the two theories is abundantly evident from the fact that with equa. (1) an expression for the elastic pressure of a gas may be obtained that is a counterpart of that given by the equation of Clausius, viz: $pV=\frac{2}{3}T-\frac{2}{3}\Sigma\Sigma\frac{1}{2}Rr$. This may be inferred from the general consideration that the impulses upon any point, O, of the enclosure, of an ethereal wave in which the velocity of the radial pulsation increases from zero to a maximum, u, and then decreases to zero, is analogous to the impulse of a gaseous molecule whose velocity, u' is reduced to zero, and then restored in the recoil—the ethereal waves and the gaseous molecules alike impinging on the point from every variety of direction. To show it conclusively, let it be borne in mind that the central atoms of the molecules of the gas may, for each point O, of the enclosure, be conceived to be uniformly distributed over the surface of a hemisphere described around this point, so

that each elementary part of the surface will be occupied by one such atom, and so will be a center of radiation of wave-impulses propagated to O (p. 436). Now let u be the maximum velocity of pulsation of the ethereal atoms in any wave, at the point O; m the mass of ether effective in the pulsation; s the minute space (equal to half the length of a wave) over which m moves while the velocity is increasing from zero to u, or decreasing from u to zero; and p_1 the mean impulsive force taking effect over the space s. Then for the wave impulses propagated along the normal at O, $p_1 \times 2s = mu^2$. Let n_1 denote the number of successive waves in the space, 1, and take for the unit of time the interval employed by the wave in traversing the distance, 1; and we have $n_1 = \frac{1}{2s}$ and $p_1 \times 2s \times \frac{1}{2s} = n_1 mu^2$, or $p_1 \times 1 = n_1 mu^2$. But $p_1 \times 1$ is the impulsive work of the waves in the unit of time, and may be taken as p', the force of pressure on an elementary area at O, due to the successive waves propagated along the normal at O. Now for a wave coming from a direction inclined under any angle φ' to the normal, the normal impulse will be $p' \cos \varphi'$, and the normal velocity of pulsation will be $u \cos \varphi'$. Thus $p' \cos \varphi' = n_1 mu^2 \cos^2 \varphi'$; and for n' molecules having this angle of direction, $n' p' \cos \varphi' = n' n_1 mu^2 \cos^2 \varphi'$. For the entire normal impulse at O, or the elastic pressure, p, on an elementary area at O, we have then, $p = \Sigma n' n_1 mu^2 \cos^2 \varphi$. But the gaseous molecules lying in any angle of direction, φ, around the normal, form an elementary zone of the hemisphere, whose breadth is $d\varphi$, and altitude, in the normal direction, $d \cos \varphi$, or $\sin \varphi d\varphi$. If then n represent the number of molecules in the entire hemisphere, $n' : n :: \sin \varphi d\varphi : 1$; and $n' = n \sin \varphi d\varphi$.

$$\text{Thus } p = \int_0^{\frac{\pi}{2}} nn_1 mu^2 \cos^2 \varphi \sin \varphi d\varphi = nn_1 mu^2 \left(-\frac{\cos^3 \varphi}{3} \right)_0^{\frac{\pi}{2}} =$$

$$\frac{nn_1 mu^2}{3} = \frac{2}{3} \cdot \frac{nn_1 mu^2}{2}. \quad \text{Now } \frac{nn_1 mu^2}{2}$$

is the entire living force, or energy, of all the ethereal waves occupying at any interval of time the space unity on all the lines radiating from O; or included within a hemisphere traced around O with the radius 1. Calling this E, we have $p = \frac{2}{3}E$. But the hypothesis, which has been tested by quantitative determinations (p. 437), that the repulsive term in equ. (1) varies inversely as the cube of the distance, x', between the centers of the molecules, gives the same law of variation for the impulses received at O; and accordingly if T denotes the value of E, when $x' = 1$, $p = \frac{2}{3} \frac{T}{x'^3} = \frac{2}{3} \frac{T}{V}$, in which V is the volume occupied by a given number of molecules, N, in terms of the volume, 1,

occupied by the same number of molecules when the distance between their centers is 1.

If now we take account of the attractive impulses answering to the attractive term in equ. (1), it is plain that by a similar investigation we shall obtain for the diminution, d, of the elastic pressure at O, $d=\frac{2}{3}E'$. Accordingly for the actual pressure on an elementary area at O, we have

$$P=\tfrac{2}{3}E-\tfrac{2}{3}E'=\tfrac{2}{3}\frac{T}{V}-\tfrac{2}{3}E'=\tfrac{2}{3}\frac{T}{V}-\tfrac{2}{3}\frac{T'}{f(V)};$$

where T′ denotes the entire energy of the attractive waves that occupy at any instant a hemisphere described around O with the radius 1. It may be shown that unless the number of atmospheres of pressure be great, $f(V)=\text{const.}\,(V)^{\frac{3}{2}}$, approximately. This expression for P is, essentially, the counterpart to the value of p given in the equation of Clausius (p. 441). The first term is directly proportional to the coefficient of repulsion, m, and so to the temperature reckoned from the absolute zero; and inversely proportional to the volume, V, occupied by a given number of ultimate molecules, N. The other term varies from one gas to another proportionally to the coefficient of attraction, n, and varies for the same gas with the volume occupied by the same number of molecules, N; but does not change with the temperature, except as the volume may vary with the temperature, and the value of n also. In view of the result of this investigation it is hardly necessary to add that all the objections which have been urged against the doctrine that the elastic pressure of a gas is due to statical molecular repulsion are entirely inapplicable to the present theory.

For calculating the gaseous pressure in atmospheres I obtain the formula

$$P_t=\overset{\text{atmos.}}{1}\times q\left\{1-\frac{kq\left(3+\frac{236}{q^{\frac{1}{2}}}\right)}{13{,}924\left(1+\frac{q^{\frac{1}{2}}}{118}\right)^2\left(1+\frac{q^{\frac{1}{2}}}{59}\right)^3}\right\}\left(\frac{288{\cdot}^\circ5+t^\circ}{288{\cdot}^\circ5}\right)$$

in which $\frac{1}{q}$ = ratio of the volume, in the case of an ideal gas for which $k=0$ and $\frac{m}{x^3}\div\frac{m'}{x'^6}$, answering to the assumed value of u, to the volume at the pressure of one atmosphere, and the mean temperature, 15°·5 C., occupied by the same number of molecules; t° = temperature above the mean taken as a zero point, k = ratio of coefficients of attraction and repulsion, as before, for the gas and temperature considered. The value of k varies with the temperature. We have already seen (p. 439)

that for a certain mixture of oxygen and hydrogen its estimated value is about $2\frac{1}{2}$; and that for carbon-dioxide it is 3·17, when the gas is in the condition and at the temperature referred to on page 438, and increases as the temperature falls, to 4·93 at about the temperature, −80° C. At the critical temperature 30·°9 C., its value is 4·7.

The approximate value of k for any gas at any temperature may be readily obtained, for any other temperature for the same gas, by the empirical law that it is inversely proportional to the $\frac{1}{7\cdot5}$ power of the absolute temperature. It is to be understood that the calculations are for the value of k at the maximum tension of the gas (vapor) at the temperature considered.

In the liquefaction of oxygen, hydrogen, and nitrogen, when the point of liquefaction, so styled, was reached, the distance, x, between the molecules, must have been reduced to $3\cdot5r$, or very nearly this. This distance answers to the point of ebullition of gases whose molecular curve lies just above the critical curve (for which $k=4\cdot7$). By specific heat ratios we obtain for oxygen, $k=4\cdot93\times\frac{0\cdot9765}{1\cdot96}=2\cdot456$. The reduction of temperature from 15·°5 C. to 145·°5 C. should materially augment this deduced value of k. If we assume that the empirical law holds for oxygen, as for carbonic acid, that k is inversely proportional to the $\frac{1}{7\cdot5}$ power of the absolute temperature, we obtain $k=2\cdot64$. Now taking $u=3\cdot5$, I find $q=1156\cdot2$. Taking this value of q, and $k=2\cdot64$, the formula gives $P_{,}=272\cdot5$ atmospheres. The volume ratio for the actual gas, for which $k=2\cdot64$, I find to be $\frac{1}{650\cdot9}$. This gives for the density of the condensed gas, 0·881 the maximum density of water; on the hypothesis that the dimensions of the molecules are unaffected by the reduction of temperature. But theoretically this should be attended with a contraction of the effective molecules. If we assume the law of the consequent diminution in the volume of the gas to be the same as that of the increase of k from a fall of temperature, the density comes out 0·94. According to Professor Pictet's experimental determinations the elastic pressure of the condensed oxygen was 273 atmospheres; and the density 0·98.

If we suppose the original value of k (2·456) to remain unchanged and take $u=3\cdot5$, the formula gives $P_{,}=285$ atmospheres; and the density comes out 0·936, and after correction for temperature, 1·00. For $k=2\cdot6$, and $u=3\cdot5$, $P_{,}=277$ atmospheres; and the density is 0·91, or 0·975. For $k=2\cdot63$, and $u=3\cdot5$, $P_{,}=273\cdot6$ atmospheres; and the density is 0·888, or 0·952.

At the point of incipient condensation of carbon-dioxide, just below the "critical temperature" (31° C.), for which $x=7{\cdot}3r$ I find $q=271{\cdot}14$. With this value of q, and $k=4{\cdot}7$ I obtain $P_1=72{\cdot}2$ atmospheres. Dr. Andrews found the elastic pressure at the critical point to be 75 atmospheres. The small discrepancy results from the fact that the precise critical curve is slightly below that for $k=4{\cdot}7$, and the corresponding molecular repulsion is greater in the ratio of 51, or 52, to 40. Making the correction, we have for P_1 75 or 76 atmospheres.

These two examples must suffice for the present as illustrations of the applicability of the formula, and verifications of its accuracy.

From the point of view I have taken, chemical combinations consist, essentially, in changes effected in the condition of the molecules of the constituents, by which they are brought into approximate correspondence, and take up the relative positions suited to that uniform condition, just as a mass of similar molecules in that state would do. The change of state consists simply in the nearer approach of the envelopes to the central atoms of the molecules, or in a recess from them, from which results a change in the value of the ratio k, and in the corresponding curve of effective action. The determining cause of this change is the difference in the mechanical condition of the dissimilar molecules, more or less enhanced by the unequal operation of heat or electricity. The immediate result may be either an expansion of the one molecular envelope and collapse of the other, or a collapse of both incited by a flow of electric ether from the source of heat or electricity. The union of chlorine with hydrogen may be cited as a probable instance of the former, and the combustion of hydrogen as an instance of the latter. When metals are oxidized, or solids undergo combustion, we must suppose there is a flow of electric ether from the solid to the oxygen molecule, and the former molecule expands somewhat while the other contracts to the dimensions answering to the solid condition.

Heat, in its association with molecules, consists of the energy of recurring pulses and vibrations in the molecular envelopes, and has two modes of motion or two dynamical aspects, *radial* and *tangential*. The energy connected with the former, is the origin of its expansive force. The propagation of the latter, in ethereal waves of transverse vibration, constitutes the radiant heat emitted by bodies.

Heat energy may be expended not only in the expansion of bodies, but also in augmenting the potential energy of the individual molecules by enlarging their envelopes. In this way a certain amount of heat becomes latent in the process of liquefaction. A portion of the heat of vaporization is expended

in a similar manner. The enlargement of the envelopes here alluded to consists in a recess of the effective envelopes from the central atoms. This should be attended with a certain diminution in the value of r, the distance between the centers of attraction and repulsion posited within the envelopes; and therefore with an increase in the value of $p\left(=\frac{m}{r^2}\right)$. In fact the quantitive determinations I have given, when compared with the results of experiment, indicate that p is materially larger at the same temperature, for liquids and aeriform bodies than for solids. An important tendency of the diminution of the value of r in liquefaction, is to antagonize the expansion directly due to the enlargement of the effective molecules and the attendant diminution in the coefficient n. According as the one or the other of these two tendencies preponderates, the mass will expand, or contract in the act of liquefaction. In the case of any special solid or liquid, the diminution of r with a rise of temperature tends to diminish the expansion, and by increasing p to make the decrement of tenacity less. Any differences in the value of r that may subsist with molecules of different substances, at the same temperature, can only have the effect to alter the positions of the substances on the molecular scale. Any changes or differences that may occur in the value of r, in the case of the gases, will have no effect on the molecular repulsion at those distances, x, for which F, in equ. 1, is sensibly equal to the second term, and therefore, as we have seen, the law of Mariotte holds good; since the repulsion will still be the same for the same actual distance between the molecules. At less distances the tendency should be to alter slightly the deviations from this law.

The value of the coefficient of attraction, n, depends on the excess of the attraction exerted by the central atom of a molecule on its envelope, over the repulsion exerted on it by the condensed luminiferous ether posited between the atom and envelope. The tendency of a recess of the envelope from the atom may be either to diminish, or augment the value of n. It thus may happen that by an increase of n, and a diminution of r, the value of F may be augmented by a certain rise of temperature; as when a bar of wrought iron is heated up to about 400° F. In the case of gases n may change somewhat with the temperature, and in the process of condensation.

The normal type of solidity is a fixed distribution of the ultimate molecules at the angles of successive cubes; and the fundamental principle of the stability of every such elementary cube is that each molecule is in equilibrium, by itself, with each of the others. As the distances are unequal, this implies that k is smaller in the diagonal direction than in the

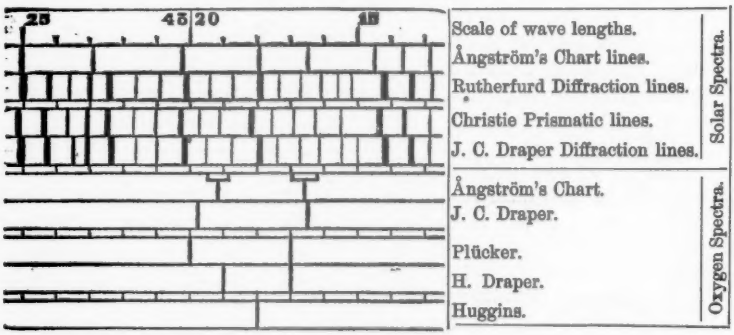
direction of the sides; and thus that the extension, or physical condition of the envelope is unequal in these directions. It is in this sense that "polarity of atoms" (ultimate molecules) exists. Instead of being an inherent property of the atoms, it is liable to change with varying relations to other molecules. When the mass varies in density from one point to another, there is a gradual variation in the size of the elementary cubes, or a gradual transition from cubes to parallelopipedons, or other geometrical figures, with attendant variations in the curves of effective molecular action. The molecular envelopes of different substances may be liable to different varieties of polar condition under the same circumstances, and so the substances may have different types of solidification, or crystallization. For the cubical system I obtain as the complete expression for the elastic resistance to a minute displacement of a single molecule, $f+2f'+1\frac{1}{3}f''$; in which f is the force of resistance developed between the displaced molecule and that lying in the direction of the side of the cube, by a displacement s, in this direction; f' the force of resistance of a molecule lying in the direction of a face diagonal, for the same displacement s, in this direction; and f'' the corresponding resistance of a molecule in the direction of the long diagonal. The value of the expression is the same in whatever direction the displacement occurs. The expression for the lateral force developed, as well as for the elastic resistance to shearing, in the direction of a side of the cube is $f'+1\frac{1}{3}f''$. For any reasonable suppositions that can be made with regard to the comparative values of f, f', and f'', the ratio of these two expressions lies between $\frac{1}{2}$ and $\frac{1}{4}$. The experimental ratios fall between these limits. The resistance to shearing is due to the diagonal forces.

When a body is heated to the point of liquefaction, the values of f' and f'', considered as resistances to tension, which are always less than f, vanish (that is, the curves fall below the axis of x). There is therefore no shearing resistance; which is one of the distinguishing features of a liquid. When the temperature of the liquid is raised above the point of liquefaction, effective repulsions must come into play in the diagonal directions. These repulsions are the operative cause of surface evaporation; and at the same time originate at the surface the "contractile force" which, by the variations it experiences from the contact of solids, is the determining cause of capillary phenomena.

Yale College, Nov. 30th, 1878.

ART. LVII.—*On the Dark Lines of Oxygen in the Solar Spectrum on the less refrangible side of G;* by JOHN CHRISTOPHER DRAPER, M.D., LL.D., Professor of Natural History in the College of the City of New York.

IN a paper on the lines of oxygen, published in this Journal for October, 1878, the solar lines closely coincident with those of the electric spectrum of oxygen were given. The measurements of the solar lines in that instance were taken from photographs made in March, 1878. Since that time, under more favorable atmospheric conditions, I have succeeded in obtaining finer photographs on the less refrangible side of G. These show many faint lines, not visible in the photographs of March 1878, while many other lines are distinctly sub-divided. Three of the recent photographs were taken on the same day, during the last week in November, and two have been taken since that time; one during the last week in January, and one during the first week in February. In all five of these photographs faint lines are visible between λ 4316 and λ 4320, of Ångtsröm's scale, and they all show them in the position indicated by the diagram and table. The fact that all the photographs agree in their representation of these lines, is, I think, proof positive of the correctness of the positions assigned.



To place the question of the oxygen lines in this region as clearly as possible before the reader, I have devised a diagram which represents the facts regarding this portion of the solar spectrum, together with the wave lengths of the oxygen lines obtained from the electric discharge in air, and in oxygen gas. The final drawing of the diagram was made for me by my assistant, Mr. Sickels, from the wave lengths given in the table at the close of this article. The drawing was on the scale of one centimeter to each wave length. This was photographed

down to one-half its size by a photo-engraving operation. From the plate so produced, the diagram was printed. For accurate work the figures in the tables should be employed.

The first space of the diagram beneath the scale of wave lengths gives the positions of the solar lines of Ångström's chart.

The second represents measurements made from one of Dr. Rutherfurd's paper prints of this region. These measurements were made after I received Mr. Christie's paper, with a view to the detection of any difference between Dr. Rutherfurd's photograph and my own.

The third space contains a presentation of the lines of this region as given by Mr. W. H. M. Christie, of the Royal Observatory at Greenwich, in the Monthly Notices of June, 1878. This I did not receive until the latter part of last January, when I was much pleased to find the close coincidences of our results, although they were obtained by entirely different methods, and without any knowledge of each other's work. Line by line Mr. Christie's map is the counterpart of the spectrum I had mapped from the photographs taken during the last week in November, and since that time. Not only do these maps agree very closely in the placing of the lines, but the similarity in intensity is also marked. The presence of these faint lines in Mr. Christie's prismatic spectrum settles any objection that might be raised on the ground of their being interference lines in the diffraction spectrum.

The fourth space presents the measurements of my recently taken photographs. The accuracy of adjustment to Ångström's scale is shown by the coincidences in the lines λ 4312·8 and λ 4325·2. The comparison of this with my reading of Dr. Rutherfurd's photograph, as given above, while it shows slight differences, is a very satisfactory evidence of the reliability of the photographic method of investigating this problem. It is also a refutation of the objections raised by some to my system of measuring and studying the lines of the solar and other spectra. Indeed, with proper lenses, and in competent hands, the process I have followed is not only very reliable, but the apparatus may be truly regarded as an instrument of precision. Of these I hope to give ample proof hereafter.

The position of the lines in this region of the solar spectrum being established by three independent observers, and the question of primary importance, as Mr. Christie justly calls it, settled; we pass to the examination of what these lines probably represent. First: Oxygen. Beneath the four charts of the solar spectrum, I have placed five sets of measurements of the oxygen lines in the vicinity of G. Beginning below, Huggins gives a single line at λ 4318. The other observers all

Oxygen Spectra. | Solar Spectra.

divide this, H. Draper places the two branches at λ 4317 and λ 4319; Plücker at λ 4317 and λ 4320. My own readings are at λ 4316·50 and λ 4319·75. Those of Ångström's chart are at λ 4316·57 and λ 4319·15.

In the above measurements, those for the more refrangible line are all within one-half of a wave length. The readings of the other line are within one wave length. In these positions there are, therefore, oxygen lines, and in the same regions of the solar spectrum, Dr. Rutherfurd, Mr. Christie, and myself, agree in finding faint dark lines. More than this; granting that the forked symbols of Ångström's chart indicate, (and I cannot understand what else they mean) that the observer believed that the line λ 4316·57 is divisible into two lines, placed at λ 4316·20 and λ 4316·95, and the line λ 4319·15, into two, placed at λ 4318·85 and λ 4319·45, we find that the three charts of the solar spectrum gives lines which are very nearly coincident with the readings of these forked symbols. It is not often that the results obtained by so many independent investigators agree as closely regarding a problem to be solved only by observation and experiment, and considering the smallness of a wave length, and the difficulty of making such measurements, the agreements must be regarded as favoring strongly the identity of these feeble lines of the solar spectrum with the lines of the electric spectrum of oxygen.

Among the obstacles in the way of comparing the electric lines of oxygen with those of the solar spectrum, and which in part explains the discrepancies that exist in the measurements of the lines of oxygen, is the difficulty in making exact measurements of these lines. Of this difficulty Plücker speaks in a memoir on the oxygen spectrum in the Phil. Trans. for 1865. In the same memoir he also discusses the variation in the breadth of the lines, and the variation in this variation, in different parts of the electric spectrum of oxygen. The positions given by Plücker and myself agree closely, although he gives no fractions. We both used two prisms of flint-glass, though at times he used four. Plücker's results, and my own, were obtained in pure oxygen gas, while those of H. Draper, and of Ångström's chart, were from the electric spark in air. This may possibly explain why they agree in differing slightly from Plücker and myself.

In the measurement of the lines of the solar spectrum made by Mr. Christie, the spectroscope was, he says, equal in dispersion to fifteen prisms of 60°. Dr. Rutherfurd's photographs and mine were made by means of Rutherfurd's gratings of over 17,000 lines to the inch, mine being by reflection and in the second order. The great dispersion thus brought to bear upon the solar spectrum, is, I think, the explanation of the sub-

division in that spectrum, of the electric oxygen lines given as two, by Plücker, H. Draper and myself. I do not know what the dispersion power was, nor the exact electric conditions that gave the forked symbols of oxygen in Ångström's chart; but whatever the dispersion, and whatever the electric, and consequent thermal or other condition, they seemed to have produced results very close in their relation to those in recent photographs of the solar spectrum.

Discussing the existence of bright lines of oxygen in the solar spectrum at λ 4317 and λ 4319, Mr. Christie directs attention to the opposing fact, that the spaces at λ 4315 and 4321·5 on Dr. Rutherfurd's photograph are both brighter than those at λ 4317 and λ 4319. This is also shown by my photographs, in which the slit was sufficiently narrow. I may add, that there are in my photographs, and in that of Dr. Rutherfurd, in the region from 4290 to 4301, many lines brighter than any in the spaces mentioned. Accepting these as being the true measures of brilliancy of the bright background of the spectrum in this region—and there is no reason why we should not do so—we are justified in saying, that from λ 4314 to λ 4322, and particularly in the vicinity of λ 4317 and λ 4319, there is something in the solar envelopes, which by absorption, reduces the brilliancy of the spectrum. In addition there are also faint lines which occupy the positions of certain electric oxygen lines.

If these faint dark lines are not the result of the action of oxygen, to what other cause are they to be attributed? Besides the well marked lines of calcium and titanium, no one places lines of any element here except Huggins, who claims a weak strontian line at λ 4319, and a carbon line as given at λ 4320, in Watts' Index. The space from λ 4315 to λ 4318 is free from any claimant, and here there are lines, representing the position of the line of oxygen, upon which nearly all the measurements closely agree. It appears to me that this want of any other explanation, is a fact of importance by no means to be overlooked, in arriving at the true solution of the problem of the oxygen lines.

In the table, the wave lengths of all the lines of the solar spectrum in this region are given, according to Ångström's scale. In Dr. Rutherfurd's photograph, I think, several of the lines are subdivided, according to the figures presented in the last column. An inspection of the original photograph of the spectrum itself is required to decide this matter, as the enlarged paper print in my possession is not entirely satisfactory, giving only the appearance of subdivision as I have recorded.

Conclusions.—1st. The regions in the solar spectrum at λ 4317 and λ 4319 claimed as bright lines of oxygen, are not as bright as others in their immediate vicinity.

2d. The solar spectrum shows faint dark lines in the region about λ 4317 and λ 4319.

3d. Oxygen is the substance which can produce dark lines in this region, therefore we must attribute them to the presence and action of that element.

Ångström's Chart Elements.	Solar Spectra.				Oxygen Electric Spectra.					Additional Subdivisions. Rutherfurd's Photograph.
	Ångström Chart.	Rutherfurd.	Christie.	J. C. Draper.	Air. Ångström.	Oxygen. J. C. Draper.	Oxygen. Plücker.	Air. H. Draper.	Huggins.	
	4312·85	4312·8[4]	4312·85[1]	4312·85[4]						
Ti	13·67	13·4[8]	13·60[7]	13·40[9]						
Fe	14·50	14·2[10]	14·35[9]	14·20[10]						14·0[6] 14·2[9]
		15·2[1]		15·00[0]						
		15·6[0]	15·50[1]	15·45[0]						
		16·1[3]	16·25[3]	16·15[3]	16·20					16·0[3] 16·2[2]
	16·50	16·7[1]	16·90[0]	16·72[1]	16·95	16·50[3]	17·00[6]	17·00[3]		16·5[1] 16·9[0]
		17·3[1]	17·55[1]	17·40[1]						
Ca	17·95	17·9[9]	18·15[3]	17·95[9]					18·00[6]	17·8[7] 18·0[3]
		18·7[2]	19·10[1]	18·75[2]	18·85			19·00[3]		
		19·4[1]	19·70[1]	19·50[0]	19·45	19·75[3]	20·00[3]			19·2[1] 19·6[1]
Ti	20·25	20·1[3]	20·25[3]	20·13[3]						20·0[5] 20·2[5]
		20·9[4]	21·03[4]	21·00[3]						20·8[4] 21·0[1]
		21·6[1]	21·70[0]	21·65[0]						
		22·4[3]	22·50[3]	22·23[0]						22·3[7] 22·6[3]
Ti	22·90	23·0[7]	23·10[7]	23·10[3]						
		23·6[4]	23·70[5]	23·50[6]						
		24·2[7]	24·40[9]	24·25[9]						
Fe	25·05	25·0[10]	25·18[9]	25·03[10]						24·8[9] 25·2[9]

The value 0 is given to exceedingly faint lines.

Art. LVIII.—*On the Genesis of Cinnabar Deposits;** by S. B. Christy, Ph.B.

The study of the origin of mineral veins has developed no fact more clearly than the great importance as a transforming agent of solutions of the alkaline sulphides and carbonates. A constantly increasing number of geological phenomena are being explained by their influence, and the importance which was given to the sublimation theories by the older geologists is gradually diminishing.

The ores of mercury, however, partly from the fact that they have been but little studied, and partly from the ease with which they are volatilized, together with the difficulty of accounting for their solution in any of the reagents which exist in nature, have generally been regarded as formed by sublimation. Even in so recent a work as that of M. H. Kuss, (Mémoire sur les Mines et Usines d' Almaden, reprint from Annales des Mines, p. 47), the author says: "We should always recognize in cinnabar the character of a vein substance carried to the surface very probably in a state of vapor."

The purpose of the present paper is a discussion of the two theories as to the formation of cinnabar deposits. We shall endeavor to find an answer to the question, "Are cinnabar deposits produced by sublimation, or are they deposited from solution?" In considering this question, it will be necessary to briefly review the facts to be explained, and the present state of knowledge of certain of the compounds of mercury. The subject will therefore be divided as follows:

First. The facts to be explained—a brief synopsis of the nature of some of the more important cinnabar deposits.

Second. Some of the more important properties of cinnabar.

Third. The results of some original investigations upon this subject.

Fourth. A comparison of the relative probabilities of the two theories.

First.—The Characteristics of some of the more important Cinnabar Deposits.

I begin with the deposit with which I am personally acquainted, that of New Almaden. This has already been well described by Professor Silliman in this Journal, but a statement of its principal points may not be out of place.

The New Almaden quicksilver mine is situated about thirteen miles southwest of San Jose, California, in a low range of

* A paper read before the Geological Section of the California Academy of Sciences, Dec. 14, 1878.

hills. This range begins at the Hacienda Creek and runs parallel to the Coast range for about four miles, where it is cut by the Guadelupe Creek. These hills, so far as exploited, are composed of serpentines overlaid by magnesian schists which are nearly always black. On analysis they were found to contain, besides silicate of magnesia, a great deal of iron and considerable alumina. Overlying these are other schists, which become more and more aluminous, until finally they change into clay slates. These latter rocks are everywhere greatly metamorphosed, in some cases so much so, that they approach the darker ferruginous varieties of jasper both in appearance and hardness. All of these overlying schists have the same general dip as the surface of the hills themselves, modified of course more or less by subsequent erosion. The serpentine gave as the result of qualitative analysis, large amounts of magnesia and silica, with smaller amounts of iron and alumina, and traces of chromium, manganese, calcium and nickel.

Lying between these magnesian schists, to which the Mexican miners have given the name "Alta," and the Cornishmen "Hanging Wall," and the serpentine beneath is found the deposit of cinnabar. The "vein matter" itself appears to be a serpentine somewhat altered by infiltrated waters. It is sometimes extremely hard and tough and difficult to mine; at other times it is soft and fragile. A qualitative analysis of a specimen of the former kind selected by the mining captain as the hardest rock in the mine proved it to contain besides the cinnabar, the same ingredients as the serpentine itself, viz: hydrated silicate of magnesium, with small amounts of iron, chromium, calcium and nickel.

Associated with the cinnabar are found dolomitic crystals of pearl spar, iron pyrites, chlorite, and extremely seldom crystals of quartz. Another notable fact is the occurrence of a bituminous substance resembling idrialite. This substance is wrongly stated by Mr. Kuss, in the memoir above cited, to be "a veritable coal." It is not a true coal. It sometimes has the external appearance of a soft bituminous coal, but when heated melts and flows like bitumen. Ordinarily it is found in the liquid condition, and flows from the drusal cavities in which it is contained when they are opened. When strongly heated it gives off highly inflammable hydro-carbon vapors, and leaves an intumescent coke which is very light and fragile, and burns with scarcely any ash. Sometimes the schists spoken of are impregnated with a hydro-carbon more like petroleum, as in the 1,500 and 1,600 feet levels of the Randol shaft.

In that part of the mine known as the Cora Blanca, there is a sheet of dolomitic limestone which extends from the top to the bottom of the mine. This lies immediately beneath the Alta

in most cases, although some ore has been found above it. It varies in thickness from one to two feet. In analyzing this there was found a very small residue insoluble in the hydrochloric acid, which under the microscope proved to contain fragments of iron pyrites. (The substance had been powdered.)

In the various workings there occurs sandstone, particularly in the Cora Blanca. The sandstones seem always to overlie the "vein matter," though in the latter mine they are sometimes impregnated with cinnabar, and are said to have contained when first opened, some native mercury. The exact position and significance of these latter rocks I have not as yet been able to determine. It is altogether probable, however, that they are more or less local in their origin, being the result of slightly varying conditions which existed during their deposition. Such a supposition would account for the gradual change of the sandstones into slates, which often takes place in such a manner as to make it difficult to determine to which class to assign them.

Native mercury occurs rarely; chiefly in the sandstones of the Cora Blanca, but also in the 1,500 and 1,600 feet levels of the Randol shaft, where it ran out of the shattered Alta upon opening out the vein-matter at places where it was much broken up by faulting.

In many cases the micro-crystals of cinnabar are most intimately mixed with those of dolomite, and occasionally with those of quartz. The cinnabar even when apparently pure to the eye, is so thoroughly impregnated with bitumen that a lump of it when distilled out of contact with the air leaves a carbonaceous residue.

Throughout this interesting mine there are many evidences both of chemical and of mechanical action.

A strongly alkaline spring with free carbonic acid (the New Almaden Vichy spring) is still active at the Hacienda. Occasionally springs with sulphydric as well as carbonic acid are opened by the drifts. In the mine "slickenslides," or surfaces polished as smooth as glass by slipping on each other, are frequently met with; and often large masses of serpentine are broken off bodily and are buried in the superincumbent mass of Alta.

The ore is very irregularly distributed throughout the vein-matter, frequently disappears altogether and reappears in such an uncertain manner that, despite the well established course of the ore body, or rather of the "alta" or "hanging wall," there is required a great deal of skill and judgment for the proper exploitation of the mine.

The Gaudelupe and the now abandoned Enriquita mines

appear to belong to the same formation; but it would require a thorough examination of all of this series of mines to trace out this and other interesting questions. I have dwelt thus long upon some of the characteristics of this mine because it is in many respects typical.*

Von Cotta in his *Erz-lager Stätte*, vol. ii, p. 616, gives the following as the characteristics of the principal cinnabar mines of Rhenish Bavaria, Bohemia, Alps, Upper Italy and Spain:

Country Rocks:—Sandstone, clay-schists, trachyte, talcose mica slate, limestone and quartzose mica slate.

Ore matter.—Cinnabar, blende, galena, tetrahedrite, limonite, amalgam, copper pyrites, iron pyrites, silver ores, native quicksilver, horn quicksilver, idrialite, lebererz, magnetic iron pyrites.

Vein filling.—Quartz, hornstone, heavy spar, calc spar, dolomite, spathic iron, gypsum.†

Such a general distribution of carbonates certainly argues against the sublimation hypothesis. With a few exceptions these cinnabar deposits are not in *immediate* relation to igneous rocks, but are nearly always found in metamorphic rocks. In some cases, seven out of sixteen, Von Cotta describes these deposits as veins, the others as in clefts (*klüfte*), layers or impregnations. Usually, with the notable exception of Almaden in Spain, cinnabar does not seem to occur in true fissure veins, but rather to be interspersed in the ore body in a very irregular manner, as is indicated by the term "impregnation."

Second.—The Chemical Properties of some of the Salts of Mercury.

The inquiry here becomes at once limited within very narrow boundaries.

The stable salts of mercury which could exist in any natural mineral waters are very few. The mercuric chloride is at first sight the most probable one, the sulphate not existing in solution except in the presence of a free acid. Still, salts of mercury have been proved to exist in at least one mineral water. In the analysis of the spring "du Rocher,"‡ there is given as a constituent of the water a small amount of mercury. It was very small; the total amount of all the heavy metals, including mercury, estimated together was only 0·008 grams per liter. But the author states that he obtained enough mercury from 500 liters to exhibit it in the metallic state.

* For another description of this and other deposits in California, etc., with other interesting facts, see "Les Gisements de Mercure de Californie," par M. G. Rolland," Annales des Mines, 1878, and also "Bulletin de la Société Minéralogique de France, 1878; Bull. No. 6."

† For a full description of the deposits of Almaden in Spain, see the article of Mr. Kuss above cited, pp. 10–49, or translation by the writer, pp. 6–19–20.

‡ St. Nectaire-le-haut, Puy-de-Dome, by M. Garigon, Comptes Rendus, vol. xxxiv, p. 936.

It seems much more probable, however, that the salt of mercury usually regarded as the most insoluble is the one in which we are directly interested, i. e. the mercuric sulphide. This salt, while insoluble in almost everything else, is well known to be soluble in solutions of the alkaline sulphides containing free alkali. This fact is recognized both by Rose and Fresenius, but I have been unable to find any exact statements as to the degree of solubility. Prof. V. Stein, in Dingler's Polytechnisches Journal, vol. cxxxviii, p. 390, states: "I found that sulphydrate of sodium as well as potassium dissolved cinnabar even in the cold with the same ease as water dissolves sugar." This statement is, to say the least, a great exaggeration. He also states that the polysulphides of the alkalies failed to dissolve any noticeable trace of the sulphide of mercury. Fresenius* finds that yellow sulphides of ammonium dissolve traces of sulphide, of mercury, particularly in the cold. Barfoed† states that while sulphides of sodium and potassium dissolve mercuric sulphide sulphydrates of the alkalies, as well as sulphydrates to which sulphur has been added, fail to do so.

On the other hand, Dr. R. Weber‡ states that he found that sulphide of potash dissolves the mercuric sulphide only in the presence of free potash or soda. Moreover, that the addition of carbonic acid, sulphydric acid, or flowers of sulphur, precipitates the mercury from such a solution completely.

Again it is well known that the polysulphides of the alkalies change the black variety into cinnabar, which could hardly be the case unless partial solution had taken place. Also, that when mercuric sulphide is slowly deposited from such solutions cinnabar results, but when rapidly deposited as by dilution, etc., the black or amorphous modification; finally, that cinnabar volatilizes out of contact with the air at a little below red heat, depositing cinnabar when slowly cooled, and the amorphous variety when rapidly cooled.

Such in brief is at present the not altogether satisfactory state of knowledge on this subject.

Third.—Experiments upon the Solubility of Mercuric Sulphide in Solutions of the Alkaline Sulphides at high temperatures and pressures.

The great difficulty of accounting for the deposits of cinnabar in the wet way has always been the difficulty of finding any natural solvent for this substance. The experiments of Weber, cited above, show that as soon as the free alkali is neutralized either by carbonic or sulphydric acid the mercuric sulphide is precipitated completely from its solution in the alka-

* Zeitschrift für analytische Chemie, vol. iii, p. 140.
† Journal für praktische Chemie, vol. xciii, p. 244.
‡ Poggendorff's Ann. d. Phys. u. Chem., vol. xcvii, p. 76.

line sulphides; and, as free alkali is not known to exist in any natural mineral waters, the question has still remained, "In what has this substance been dissolved, if we are to suppose it to have been formed in the wet way?"

The classic researches of Daubrée on metamorphism,* and those of De Sénarmont† on the formation of mineral veins in the wet way, as well as the fact that these solutions must have originally acted at higher pressures and temperatures than those of the atmospheric waters, led to the following investigations.

Impressed with the idea that moderate increase of temperature and pressure might possibly bring about the desired results, I was led to adopt a more easily manageable apparatus than that used by the investigators already mentioned.

For this purpose I used a Papin's digester of gun metal, about $7\frac{3}{4}$ inches high, $3\frac{1}{2}$ inches in outer diameter, and $\frac{5}{16}$ inch thick. This vessel was calculated to stand with safety a pressure of 650 to 700 lbs. per square inch. It was provided with a safety-valve so that the pressure could be easily regulated at any point, and as an additional check it was heated in a bath of iron filings, so that the temperature could be approximately determined. The whole was surrounded by a sheet-iron shell to guard against the danger of explosion. The digester was heated by an ordinary Bunsen burner. The substances to be experimented upon were enclosed in glass tubes usually sealed at both ends, but occasionally open at the top so as to allow the contents to slowly evaporate under pressure, after the water in the digester itself had evaporated through the safety valve.

The only disadvantage of using this form of apparatus was the difficulty of determining when the water was entirely evaporated. This led to several explosions of the sealed tubes within the digester and the consequent loss of many days' work. The joints were all made with a lead packing, as paper, leather, etc., would not resist the high temperatures at which the experiments were conducted. The highest temperatures reached were in the neighborhood of 250° C. (482° F.). The thermometer at the bottom of the bath of iron filings indicated 360° C. and at the top 150° to 200° C.

The first experiment made was with a tube containing amorphous mercuric sulphides with a solution of potassic sulphydrate (potash solution saturated with sulphydric acid.) The tube was open at the top and its contents were allowed to evaporate to half their bulk (after the water in the digester was evaporated) under a pressure of 150 lbs. per square inch. The temperature was about 180° C. The operation was continued five hours. The sulphide was entirely changed to a red pow-

* Ann. des Mines, 5 Serie, vol. xvi, p. 155 and 393.
† Ann. de Chem. et Phys., vol. xxxii, p. 129.

der and the next day the tube was found to contain a beautiful coherent mass of crystals of cinnabar, recognizable by the naked eye, simulating the crystals which occur in nature very perfectly. They appeared to be rhombohedrons, although I have not been able to determine this with certainty.

Subsequently a large number of experiments were made, all with closed tubes, upon various solutions in contact with amorphous mercuric sulphide, for the purpose of determining the action of these different reagents. The temperatures varied from about 200° to about 250° C., and the pressures from 260 to 500 lbs. per square inch. The determinations of the pressures were not perfectly exact, owing to the difficulty of making the valve-seat bear with perfect uniformity. The duration of the heating varied in the different experiments from three to ten hours, and in each case the digester with its contents was allowed to cool undisturbed till morning.

The results of these experiments are as follows:

Solutions of sodium bicarbonate did not change the amorphous variety of mercuric sulphide to cinnabar. Solutions of water-glass were equally powerless. But when through either of these solutions sulphydric acid was passed, and the tubes were again heated in the digester, the transformation was complete. Polysulphide of potassium as well as sulphydrate changed the amorphous sulphide very rapidly and completely. The presence of excess of carbonic acid seemed to retard the formation without being able to prevent it. The cinnabar formed was usually in the state of micro-crystals, like vermillion, but often they were larger and more like the native cinnabar in appearance, though they were so minute as to make the determination of the crystalline form extremely difficult. In all cases when the transformation had taken place, the liquid would stain the skin deep black, as is usual when mercuric sulphide is dissolved in alkaline sulphides. This would be an additional proof, if one were needed, that solution had taken place.

Finally, I was led to try the effect of heating the amorphous sulphide with the New Almaden Vichy water, to which sulphydric acid had been added. This water as analyzed by E. Piquet, Mining and Scientific Press, vol. xviii, p. 360, has the following composition:

"Bicarbonate of soda	50·3	grains.
Bicarbonate of lime	8·0	"
Sulphate of lime	10·5	"
Sulphate of magnesia	3·0	"
Chloride of sodium	8·4	"
Oxide of iron	1·2	"
Silica	traces."	
Carbonic acid	28·2	"

This amount was contained in a bottle of two pounds.

Sulphydric acid was passed into this water for half an hour, an equal amount of mineral water, and some black mercuric sulphide were added to it, and the mixture was treated in the digester, while a similar experiment was carried on at the ordinary pressure of the atmosphere and a temperature of 100° C. The temperature of the digester was not more than 180° C., and the pressure 140 to 150 lbs. The time in both cases was two hours. The sulphide which was treated in the open air was unchanged even when examined with the microscope, while that treated in the digester was brownish red even to the naked eye, while under the microscope it showed itself to be composed of a small amount of as yet unchanged amorphous sulphide, and a larger amount that was completely transformed to cinnabar. Crystals were not visible with the powers used.

This mineral water, therefore, when the single ingredient of sulphydric acid is added to it is capable of dissolving mercuric sulphide, and of depositing it from solution in the crystalline form when it is slowly cooled.

Fourth.—The Rival Theories.

It would be idle to attempt to follow the mercuric compounds from their existence in the nebulous mists to the ore deposits in which they are found to-day, but it is altogether probable, from the great permanence of the mercuric sulphide, that the mercury salts would be precipitated in that form soon after the waters had been deposited, and that the mercury would be found in that as sulphide in the earliest sedimentary deposits. On the one hand we have the sublimation hypothesis to account for the present position of these ore deposits, and on the other the solution theory. Now, while it is probable *à priori* that as these deposits were buried deeper and deeper by subsequent debris, that the interior heat of the earth would raise them to such a temperature that *if sufficiently extensive fissures were to occur volatilization might ensue*, and the vapors would rise upward to such points as would permit their recondensation; and while it is possible that in special cases as in the vicinity of eruptions of true igneous rocks such may be the case, at the same time *it is probable that the deposits as they exist to-day in situ are the result of the action of mineral waters, which act either by leaching out the cinnabar from neighboring rocks, or more probably by bringing it from lower rocks.*

In support of this position are the following facts: In the first place, cinnabar volatilizes only at just below a red heat (500° C.), when exposed to the ordinary pressure of the atmosphere. Now, if we take the increase of temperature as 1° C. for each 100 feet below the surface, it would take a depth of nearly

50,000 feet to give this temperature. At New Almaden, for example, which is certainly not in the immediate vicinity of volcanic rocks, since the cinnabar outcrops upon the summit of the hills, we should have to assume an erosion to have taken place of nearly nine and a half miles of strata. The age of the formation (pronounced Cretaceous by Prof. J. D. Whitney, in the Geological Survey of California), hardly admits of such an hypothesis. On the other hand it is impossible that the foldings, etc., due to mechanical action, occurring as they usually do so gradually, could have given rise to the necessary temperature. And even assuming that at the time of the formation there was a rate of increase of temperature with depth three times as great as at present, it would still require a depth below the surface of three miles to give such a temperature.

Not only so, but at such a depth the enormous pressure of superincumbent strata would greatly increase the heat necessary for sublimation. This fact is well illustrated by the case of water. The natural rate of increase of temperature due to internal heat can never be great enough to convert water into steam except by the presence of local igneous rocks. Pfaff, in his Geologie als Exacte Wissenschaft, p. 112, shows this by the following table.

Depth in feet.	Temperature. Centigrade.	Pressure of water in atmospheres.	Tension of steam in atmospheres.
10,000	100	300	1·
20,000	200	600	15·3
80,000	800	2400	1416·
100,000	1000	3000	1877·
200,000	2000	6000	2403·

The third column gives the weight in atmospheres of a column of water of a height equal to the depth; this is the minimum pressure to which it can be exposed, unless we suppose an extensive fissure filled only with air and extending far upward. The fourth column gives the tension of steam at the temperatures corresponding to the depths calculated according to Regnault's formula. It is evident that under these conditions the water will never boil at any depth except in cases of local eruptions of volcanic rocks. Although there have not been, to my knowledge, any determinations of the elastic force of cinnabar vapor, it is probably less than that of steam, and the above reasoning will apply with even greater force to this case.

In the second place, the deposits themselves, as indicated in our study of the principal cinnabar deposits, do not usually show the signs of true fissure veins, but are rather found irregularly disseminated in layers and impregnations; nor are volcanic rocks usually found in sufficient proximity to give the heat necessary for volatilization.

In the third place, the formation of many of the ore bodies cannot be explained upon the sublimation hypothesis. Many of them, notably that of New Almaden, contain carbonates so intimately mixed with cinnabar that the conclusion is inevitable that they were formed in the same, i. e. in the wet way. The occurrence of quartz and bitumen intimately mixed shows the same thing.

Again M. Kuss* himself, though evidently inclined toward the volatilization theory, admits that: "The material of the quartzite which is lacking to-day in the rocks impregnated with cinnabar, certainly could not have been missing either at the time of the first deposit of the beds or after the strong pressure which compressed and straightened them. How could this disappearance of siliceous matter be effected, matter almost inattackable by all the reagents which we can imagine to have intervened during the epoch of the formation of the veins of cinnabar?" This disappearance of siliceous matter is certainly inexplicable by the sublimation hypothesis; but by the supposition that the cinnabar was deposited from solution in a mixture of alkaline sulphides and carbonates, it is not only explained but also would be a perfectly natural consequence of the main supposition.

Still again, of the minerals which were mentioned in the first part of the paper as accompanying cinnabar, all, with the possible exception of magnetic iron pyrites, have been produced in the *wet way* by various experimenters as the following references will show.

Blende, by De Sénarmont, Ann. Ch. Phys., xxxii, 129.
Galena, by De Sénarmont, Ann. Ch. Phys., xxx, 139.
Fahlore minerals, by De Sénarmont, Ann. Ch. Phys., xxxii, 129.
Iron pyrites, by De Sénarmont, Ann. Ch. Phys., xxx, 140.
Horn quicksilver, in many ways.
Quartz, { Daubrée, ibid. / De Sénarmont, Ann. Ch. Phys., xxxii, 129.
Heavy spar, De Sénarmont, Ann. Ch. Phys., xxxii, 129.
Dolomite, Hunt, Am. Jour. Science, II, xxviii, 170, 365; xlii, 49.
Spathic iron, De Sénarmont, Ann. Ch. Phys., xxx, 153.
Gypsum, Hunt, Compt. Rend., xlviii, 1003.
Calc spar, { Becquerel, Compt. Rend., xxxiv, 29, xxxvi, 207. / Rose, Pogg. Ann., xii, 533.

The production of bituminous material similar to idrialite has been accomplished in the same way, by heating organic matter with water in closed tubes at high temperatures.† In fact this transformation is invariably regarded not as the result

* Memoire sur les Mines et Usines d'Almaden, p. 44. Translation of same by writer, p. 21.

† Daubrée, Metamorphism, Annales des Mines, 5th series, vol. xvi, II, end of chap. iv.

of *dry distillation*, but as the effect of heat in the presence of water. And if the temperature were great enough to have volatilized cinnabar, it is probable that these much more volatile hydrocarbons of the original organic matter would have disappeared, and we should have anthracite or graphite instead of bitumen, as we do in most of the cinnabar deposits.

In addition to this we have shown that the sulphide of mercury at comparatively moderate temperatures is soluble in solutions of the alkaline sulphides, *that increase of pressure aids rather than retards this solution*, and that cinnabar is deposited from such solutions in the crystallized form when the temperature and pressure are slowly lowered. We have shown that by adding sulphydric acid to the mineral spring water, now existing in the neighborhood of one of the most noted of these deposits, we were enabled to produce the same effects. For various reasons, which it is unnecessary to state here, it is probable that this spring once contained sulphydric as well as carbonic acid, and we have, consequently, in the case of the New Almaden mine, sufficient cause at least for the deposit without invoking the sublimation theory.

Again, the occasional occurrence of metacinnabarite is easily explainable by the sudden dilution of the depositing waters by waters of other springs, by water from above, or by the local mixing during the crystallization process with carbonic or other acid gases. Such a mixture of amorphous sulphide with minute crystals of cinnabar, as described by Moore, (Ueber das Vorkommen des amorphen Quecksilbersulfids in der Natur) is easily reproduced by any of these methods. No other theory so well accounts for the intimate mixture of the two varieties; for the amorphous product produced by suddenly cooling the vapor presents an entirely different appearance.

Finally, the almost universal occurrence of these deposits in metamorphic rather than in igneous rocks, accords well with the theory that *these deposits as they exist in situ are the immediate result of the action of solutions of alkaline carbonates containing also alkaline sulphides.*

There are still many other points of interest in this connection which are difficult to understand. Such, for example, are the wide spread association of serpentine and other magnesian rocks, and of the bituminous substance idrialite with cinnabar. It is possible that these are conditions as well as mere concomitants. Lastly, there remains the occurrence of native mercury to be explained. Unless we regard it as the effect of the local oxidation of a very stable compound, its appearance is well nigh inexplicable upon either hypothesis.

University of California, Berkeley, Dec., 1878.

ART. LIX.—*Notice of Recent Scientific Publications in Brazil.—O. A. Derby on the Geology of the Lower Amazonas;* by RICHARD RATHBUN.

THE Archivos of the National Museum of Rio de Janeiro, which were started in 1876, and of which only a single volume was published regularly, have again made their appearance. The numbers recently received, and issued only in the early part of this year, comprise volume II complete, for 1877, and the first half of volume III, for 1878. They are accompanied by numerous plates, some of which seem to have been carefully executed. The cause of the delay in the publication of this annual, the only one devoted to natural history memoirs in Brazil, is not given, but the high character of several of the articles contained in the present volumes, partially compensates for their late issue.

Dr. Fritz Müller, of Santa Catharina, contributes to both volumes interesting papers on certain structural points among insects, principally on the scent-bearing organs of several species of Lepidoptera, and, in volume II, treats of the correlation of the versicolored flowers of a species of *Lantana*, of Santa Catharina, and the insects which fertilize them. Dr. Lacerda, of the Museum, gives the results of his experiments with the poison of *Bothrops jararaca* and *Bufo ictericus* on several domestic animals. The second volume also contains "Notes on the Localities of Antiquities (Ceramios) of Pará," by S. Ferreira Penna, and an extended memoir, entitled "Notes on the Stone Lip-ornaments of the Archæological Collection of the National Museum," by Dr. Ladislau Netto, the director of that institution. In the third volume are two short geological and mineralogical studies of small sections in the province of Minas Geraes, by members of the School of Mines of Ouro Preto.

The paper of greatest interest to North Americans, however, is "A Contribution to the Geology of the Lower Amazonas,"* by Mr. Orville A. Derby, formerly of the Geological Commission of Brazil, but recently appointed geologist in the National Museum at Rio de Janeiro. This memoir, which occupies considerable space in volume II, is a résumé of the principal results of the explorations of the late Prof. Ch. Fred. Hartt, Mr. Derby and others, in the Amazonian valley, and adds many important facts and generalizations to those hitherto published.

The first portion of the paper is devoted to a discussion of the topography and hydrography of the basin of the Amazonas, and of the relations of the great river and its many large tributaries

* The English version of this paper was published in the Proceedings of the American Philosophical Society of Philadelphia, for February, 1879.

to the surrounding table-lands and mountain chains, which direct their courses. Mr. Derby endeavors to show that between the three sections of the Rio Amazonas, popularly called the Marañon, Solimões and Baixo Amazonas, or upper, median and lower courses, there exist not only topographical differences, but also very marked differences in geological structure. After briefly describing the general geological history of the Amazonian region, as brought out by Prof. Hartt, the author enters into a detailed account of the several formations, that have been discovered in the lower valley, the immediate subject of his article. The most important conclusions recorded by him are the following:

The metamorphic deposits composing the plateau and mountain range between Guayana and Brazil, and the central Brazilian plateau, and thus bordering the Lower Amazonian basin on the north, and forming its higher lands on the south, may be divided into two series—a lower one, consisting of highly crystalline rocks, and an upper one, of generally non-crystalline rocks. The former, which constitutes the most of the Guayanian plateau, and forms the base of that of Brazil, consists of gneiss, gneiss-granite and syenite, and has been referred by Prof. Hartt to the Laurentian. The Serra do Mar and the Serra do Mantiqueira, farther south in Brazil, are made up of the same formation.

The second or upper series, composed mostly of quartzites, metamorphic schists and crystalline limestones, probably represents both the Huronian and Lower Silurian, as an apparent difference in age is exhibited in the exposures of these rocks. To the Lower Silurian are referred, as before, the itacolumites and talcose schists of Minas Geraes. The metamorphic rocks are generally well exposed in the falls and rapids of the several tributaries of the Amazonas, the upper, or non-crystalline series being usually the first reached in ascending these rivers.

The southern edge of the metamorphic deposits of the Guayanian plateau, beginning near the Atlantic, in about 1° north, extends a little south of west to near the confluence of the Rios Negro and Branco, between latitudes 1° and 2° south; the northern edge of the same rocks in the plateau of Brazil presents a line of exposures, which pass the Tocantins, between 3° and 4° S., the Tapajos, between 4° and 5° S., and the Madeira, between 8° and 9° S. The edges of the metamorphic regions, thus defined, mark approximately the borders of the ancient channel, which existed between the primitive islands of Brazil, and in which were laid down, without great changes of level, or disturbances, the newer formations from the Upper Silurian to the Cretaceous inclusive.

There is a certain concordance in stratification between the

beds of the two series of the metamorphic deposits, but the evidence goes to prove that the older, or Laurentian, had been more or less disturbed and metamorphosed, before the deposition of the newer, although the great general movement of upheaval, that affected, and gave character to, the entire metamorphic region of Brazil, was posterior to both.

The formations above the metamorphic, so far observed in the Lower Amazonian valley, are the Upper Silurian, Devonian, Carboniferous, Cretaceous and Tertiary. The Upper Silurian immediately follows the metamorphic series, on the north side of the valley, but has not yet been recognized to the south of the Amazonas. On the Rios Trombetas, Curuá and Maecurú, where they were examined by Mr. Derby and his party, the rocks of this formation are exposed over an area of only a few miles in width, have an estimated thickness of about 1,000 feet, and rest upon felsite and syenite; they are very gently inclined, and consist mostly of thin-bedded, argillaceous and micaceous sandstones, with some massive beds of pure sandstone. In the lower part of the series, on the Trombetas, are fossiliferous beds, containing in addition to other species, *Arthrophycus Harlani* Hall, *Lingula cuneata* Con., *Orthis hybrida* Sow. and *Bucania trilobata* Con., which indicate an horizon corresponding to the Medina Sandstone of the Niagara group of North America.

The Devonian rocks occupy a broader superficial area than the Upper Silurian, but, so far as studied, are of less thickness,—about 530 feet. They have been traced northward from Ererê, where they were first discovered by Prof. Hartt, in 1870, a distance of about seventy-five miles, on the Rios Maecurú and Curuá. Three sections or groups were readily distinguished, differing from one another, both in lithological characters and in fossils. The lower, or Maecurú group, having a thickness of about thirty feet, consists entirely of coarse sandstones, and is very fossiliferous. The only fossils of this section that have been determined are the Brachiopods, which prove that the section is closely related to the Upper Helderberg of North America, but has also many characters in common with the Hamilton group.

The second or Ererê group has an estimated thickness of about 200 feet, is made up mostly of fine-grained micaceous sandstones, with some beds of black shale, and is underlaid by beds of cherts. The fossils, which are mostly Brachiopods, are in part identical with those of the Maecurú, in part, with those of the Hamilton group of North America. The upper group, called the Curuá, is about 300 feet thick, and consists almost entirely of black and yellowish shales, passing at times into shaly sandstones. The only recognizable fossils discovered

were *Spirophytons*, apparently belonging to the same species as those described from the Hamilton group of New York.

The Devonian rocks in the Ereré region have suffered greatly by denudation, and are much dislocated and divided by trap dykes, making their study very difficult. Beds apparently of Devonian age have been found as far west as the Rio Uatumá, and, to the south of the Amazonas, on the Tapajos and Xingú.

Of all the Paleozoic deposits of the Amazonian valley, the Carboniferous is exposed over the largest area, but, at the same time, presents the greatest difficulties to study. Being composed for the most part of soft rocks, it has been much denuded only widely-separated exposures remaining, of which it is difficult to determine the correlation of the several beds. It is, therefore, also impossible to estimate with certainty the thickness of the series, which probably exceeds 1,800 feet. The rocks are soft sandstones, shales and limestones, of which the latter, though having the least thickness, are the most important, from their being the best preserved and the richest in fossil remains. The fossiliferous beds, originally studied by Prof. Hartt and Mr. Derby on the Tapajos, were traced to the north of the Amazonas, on the Rios Maecurú, Curuá, etc. The different exposures, however, appear to represent about the same limited horizon, characterized by identical fossils.

The region over which the Carboniferous has been actually observed, is defined by Mr. Derby as follows: On the south side of the valley, it reaches up the Tapajos, to near the base of the rapids; westward it extends to, or beyond, the Rio Mauhéassú, situated midway between the Tapajos and Madeira, and eastward to, or beyond, the Xingú. To the north of the Amazonas, it stretches some distance northward of the region of Alenquer, partially covering up the Devonian between Ereré and the Maecurú locality, and has been found to the west, on the Rio Uatumá, and to the east, on the Rio Jauary near Prainha. There can be no doubt but that the Carboniferous really extends much farther west, and eastward, to near the Atlantic. From what has been said before, however, it will be understood that this formation is not exposed over the entire region above defined, although at one time it must have been continuous there. It was observed on the principal rivers mentioned, generally in the vicinity of the lower falls or rapids, and also at many intermediate localities, but is mostly covered up by more recent formations, or by dense forest growths, and over large tracts has been completely swept away. Notwithstanding the fact that the fossils of this group indicate an horizon, equivalent to the Coal Measures of North America, no seams of coal have yet been found on the Amazonas. The beds lie as a rule nearly horizontal.

Mr. Derby refers the sandstone hills of the Ereré series, which surround the Devonian plain of the same name, to the Cretaceous, from a study of the leaves of dicotyledonous plants, contained in some of the beds. These hills, which are composed of inclined strata, were elevated during, or at the close of, the Cretaceous age, as a broad anticlinal ridge, afterwards denuded away in the central portion, so as to uncover the Devonian plain, and leave the present series of monoclinal ridges, disposed in the shape of an ellipse.

Much of Mr. Derby's paper is also devoted to the extensive Tertiary deposits and the *varzea* of the Amazonian valley, subjects already treated of at some length by Prof. Hartt.

Art. LX.—*First Catalogue of Radiant Points of Meteors;* by Edwin F. Sawyer.

The following meteoric radiant points have been deduced from my observations, embracing the recorded paths of nearly 600 shooting stars, seen during the last two years (1877–8) at Cambridge, Mass. Among the number may possibly be found one or two doubtful positions, and a few strongly suspected and probably new showers requiring confirmation. The other positions either confirm those deduced by other observers, and heretofore considered rather doubtful, or are those of old and well established meteor systems. The limits of duration of the several showers are naturally uncertain; the results showing only the observed duration, and not the true period, which important element should receive the closest attention of observers in the future. Considerable complication has arisen from the large number of known radiants, and more attention should be given to establishing and identifying beyond a doubt the true positions of those already catalogued, with their limits of duration, than to the discovery of new and in many cases no doubt pseudo-meteor streams.

The theoretical shifting of the radiant point of a shower from day to day as the earth changes its position, should also, it seems (in the majority of cases), be practically shown in deducing the results; although the approximate character of this class of observations, renders it difficult to notice any shifting of position at intervals of less than a week. This important point should engage the attention of all observers, as going far to demonstrate the period of long enduring showers.

In deducing my results, great care has not only been exercised in regarding the peculiarities of each individual meteor mapped, such as length of path, velocity, magnitude, etc., but

No. (Sawyer).	Dates of Observations.	Radiant point. R. A.	Dec.	No. of Meteors.	Remarks.
1	1878. Dec. 31–Jan. 7.	97½°	+17°	8	Meteors faint and rapid, possibly a new shower. Radiant, very near γ Geminorum.
2	1878. Jan. 29–Feb. 3.	167	+42	7	Quite faint, short and rapid meteors. Confirms Heis (M. 2), 169°+45°, Jan. 16–Feb. 1.
3	1878. Feb. 24–26.	145	+ 8	5	Meteors very faint, with medium velocity and length of path; one stationary meteor. Denning, from Italian Met. Asso. Obs., 1872, at 147°+4°, Feb. 1–Mar. 12.
4	1878. March 26–31.	204	+34	4	Meteors quite brilliant and slow, with medium length of path. Evidently confirms Greg and Herschel, at 198°+32°, Mar. 25–Apr. 24.
5	1877. May 3–7.	223	+21	4	Meteors faint, short and rapid. Denning, at 220°+21°, April 21, 1874. Radiant near ξ Bootis.
6	1877. June 24–July 3.	287	+25	7	Meteors generally faint, short and quick. Radiant near β Cygni. Denning, at 285°+32°, June 15–17, 1877. Tupman, at 280°+29°, June 29–30, 1870.
7	1878. July 28.	337	−33	4	Meteors bright and very slow, with long paths. Herschel, at 339°–34°, July 20–Sept. 20. Seen well by A. S. Herschel, July 28, 1865.
8	1878. July 21–23.	291	+27	7	Meteors faint and quick, with medium length of path. Denning, from Italian Met. Asso. Obs., 1872, at 287°+27°, July 15–Aug. 2. Compare No. 6.
9	1878. July 23.	285	+49	5	Meteors quite bright, short and slow. Denning, from Italian Met. Asso. Obs., 1872, at 285°+44°, July 15–Aug. 2.
10	1877. Aug. 10.	43–56		41	Perseids. Meteors brilliant, with quite long paths. Duration of observation, ¼ of an hour. Horary No. 55.
	1877. Aug. 11.	43	+57	12	Observation from 9.30 to 10.30. Meteors bright and short.
	1878. Aug. 10.	44	+56½	58	Meteors very bright, short and rapid. Duration of observation 1¼ hours. Horary No. 33. Position deduced from one stationary meteor and several short tracks near the focus.
11	1878. Aug. 10.	8	+55	8	Meteors bright, short and rapid. Confirms Denning, at 8°+53°, Aug. 3–16, 1877. Radiant between α and ξ Cassiopeiæ.
12	1878. Aug. 23–Sept. 1.	282	+42	21	Active shower; meteors bright and rapid, with quite long paths. Mean of 5 positions from Greg's Table, 1876, at 281°+38°, July 29–Sept. 25.
13	1878. Aug. 25–Sept. 1.	335	+64	6	Meteors generally bright, short and rapid. Greg and Herschel, at 335°+67°, Aug. 6–31. Schiaparelli and Zezioli, at 340°+65°, Aug. 28.
14	1878. Aug. 25–30.	237	+65	11	Position well deduced; meteors bright, short and rapid. Denning, from Italian Met. Asso. Obs., 1872, at 235°+65°, Aug. 24–Sept. 14.
15	1878. Aug. 20–27.	274	+20	7	Short, quick meteors. Denning, from Italian Met. Asso. Obs., 1872, at 270°+20°, Aug. 24–Sept. 14.
16	1878. Sept. 30–Oct. 2.	23	+17	7	Strongly suspected, and possibly a new shower. Meteors quite bright, short and rapid.

No. (Sawyer).	Dates of Observations.	Radiant point. R. A.	Dec.	No. of Meteors.	Remarks.
	1878.				
17	Sept. 27–30.	3°	+21°	7	Exact. Meteors bright, short and swift. A new shower. ?
	1878.				
18	Sept. 18–27.	333	+23	5	Rather uncertain. Meteors bright, short and slow. Denning, from Italian Met. Asso. Obs., 1872, at 333°+27°, Aug. 24–Sept. 14.
	1877.				
19	Oct. 28.	356	+40	8	Position exact. Active shower, 8 recorded during ¼ of an hour; early eve. Meteors faint and short. Schiaparelli and Zizioli, at 352°+41, Nov. 13.
	1878.				
20	Oct. 17–22.	28	+33	6	Meteors generally quite bright, short and rapid. Confirmed by H. Corder, Oct. 22–31, ? 1878, at 32°+34° Radiant near ϵ Triangulorum. Possibly new.
	1878.				
21	Oct. 21–22.	47	+27	4	Faint, short and rapid meteors. Greg and Herschel, at 43°+26°, Oct. 18–Nov. 13. Denning, at 47°+28°, Oct. 8; and from Italian Met. Asso. Obs., 1872, at 45°+26°, Oct. 29–Nov. 13.
	1878.				
22	Oct. 20–29.	24	+19	9	Meteors bright, short and generally rapid. Radiant near β Arietis. Gruber, at 21°+22°, Oct. 17–24.
	1877.				
23	Oct. 30–Nov. 11.	30	+21	7	Meteors faint, with short paths. Radiant near α Arietis. Evidently confirms Tupman (94), at 30°+22°, Nov. 3, 1869. Compare No. 22.
	1877.				
24	Nov. 4–11.	60	+18	5	Taurids I. Meteors generally quite brilliant, with medium length of path. Denning, average position at 60°+20°, Oct. 17–Nov. 13, 1877.
	1877.				
25	Nov. 30–Dec. 9.	80	+22	10	Taurids II. Meteors generally quite bright and quick, with medium length of path. Denning, Nov. 25–Dec. 13, at 80°+25°.
	1878.				
	Nov. 26–29.	82	+21	9	Meteors quite bright, generally slow, with medium length of path. Principally seen on Nov. 29.
	1878.				
26	Nov. 24.	330	+63	4	Strongly suspected. Meteors faint, quick and short, and recorded during 1 hour's observation in W. Denning, from Met. Ass. Obs., 1872, at 330°+66°, Nov. 25–Dec. 31.
	1878.				
27	Nov. 23–29.	76	+46	8	Rapid, short and faint meteors. 3 recorded in rapid succession on the 24th. Position exact. Confirms a radiant deduced at Pola, Nov. 27, 1872, at 76°.5+46°.
	1878.				
28	Nov. 24–29.	25	+26	5	Meteors quite bright, short and slow. Denning, from Italian Met. Asso. Obs., 1872, at 24°+27°, Nov. 25–Dec. 31.
	1877.				
29	Dec. 1–9.	97	+16	6	Meteors generally faint, with very rapid motion. Possibly new. Radiant center very near γ Geminorum. Compare No. 1.
	1877.				
30	Dec. 7–9.	54	+35	4	Strongly suspected. Meteors quite faint and quick, with quite long paths.
	1877.				
31	Dec. 28–29.	104	+33	5	Geminids. Meteors faint, short and quick.
&	1878, Dec. 22–26.	102	+35	5	Geminids. Meteors faint, short and quick.
32	1878, Dec. 25.	114	+18	5	Meteors generally bright, short and rapid; all recorded during 1 hour's watch; good radiation. Schmidt, Jan., at R. A., 115°+15°.

during the past year a certain weight has been attached to each meteor mapped, showing the accuracy of the path recorded, on a scale of one to four, and its corresponding value used in deducing the centers of radiation; and the results are believed to be as nearly correct as the number of meteors recorded and the nature of the observations will allow. Observations were taken nearly every fair night in the absence of the moonlight, but were confined principally to the evening hours, between 6 and 11 P. M. The exceptions were morning watches in April, 1878, August, 1877–8, and November, 1877–8, for the appearance of the Lyraids, Perseids, and Leonids. With the exception of the Perseids, these gave negative results; only two or three scattering members from each stream being recorded. The periods of watching each evening varied from one to four hours in duration, and aggregate 187 hours in all. The observations were mostly confined to the eastern quarter of the sky, the few exceptions being watches in the west during the months of August, September and November, 1878.

In deducing the results, the method employed by Prof. Schiaparelli, (i. e. deducing the material obtained from each evening's observations, or those of a few evenings at most), has been used. The positions deduced from less than four meteors (of which there were a large number), have been rejected. In giving weight to the different positions deduced by me, observers should bear in mind that the small number of meteors, recorded in many of the cases, result from one or more of the following causes:

I. The shortness of the period from which each shower is deduced, averaging about five days, the average period of most observers being from twenty to thirty days. II. To the generally unfavorable hours, between which the observations were taken, before midnight, when meteors are much less abundant, than during the morning hours. III. To the small number of hours during which I was able to watch each evening, especially in the spring and winter months; several showers being deduced from one or two hours' watch only.

Corresponding observations of the same meteors are doubtless of great value in determining the heights, etc., of the meteors, as well as their radiant points, and during the latter part of last August, the writer together with Mr. Seth C. Chandler, Jr., made a series of observations at stations some seventy miles apart; the reduction of the same is now being done by Mr. Chandler.

Another series has been partly arranged and carried out by the writer and Mr. Oliver C. Wendell, of Lowell, Mass., and it is to be hoped that other observers will, during the coming year, be found willing to engage in this important work.

ART. LXI.—*Notice of recent Additions to the Marine Fauna of the Eastern coast of North America, No. 5*; by A. E. VERRILL. *Brief Contributions to Zoology from the Museum of Yale College.* No. XLII.

OF Polyzoa about 140 species have been identified by the writer from the coast between Cape Cod and Labrador. Nearly all these are Arctic or European species, already known. They are mostly described in Smitt's papers on Arctic Bryozoa. They are also mostly enumerated by the writer, in a Check-list of the Marine Invertebrata of this coast, now in type. The following is one of the more interesting new forms.

The recent determination of so large a number of American Polyzoa, confirms the decision already arrived at, several years ago, from the study of other classes, that the fauna of northern New England is remarkably arctic and chiefly of northern origin, and that the fauna of Greenland is more allied to that of Northeastern America than to that of Northern Europe. In a valuable paper* on the Podophthalmous Crustacea of our northern coast, just published, Professor S. I. Smith has arrived at the same results for that group.

Bugulella, gen. nov.

Stems slender, dichotomously branched, consisting of single series of cells (zoœcia), which are connected by short tubular joints that arise medially, from the back and near the distal end of the preceding cell, either singly or two together. Zoœcia elongated, expanded distally, with a large, sunken, elliptical frontal area on the front side, close to the end; gradually tapered to the proximal end, which is united, by an articulation, with the tubular process of the preceding cell, representing the stem. New branches arise laterally from these small joints. Frontal area surrounded by spines. Oœcia subglobular, attached to the distal end of the zoœcia. Avicularia median, at the distal end of the zoœcia, shaped as in *Bugula*. Allied to *Bicellaria* and perhaps to *Brettia*.

Bugulella fragilis, sp. nov.

Zoarium translucent, shining, delicate, filiform, much branched; forming intricate divaricate clusters, sometimes an inch or more in height. Apertures broad oval or elliptical, oblique, with a distinct rim, and with five spines, on each side; of these the two nearest the distal end are much shorter than the other three, which are as long as the breadth of the aperture, and arch over it. Sometimes a median spine is also present at the proximal edge. Ovicells globose, prominent,

* The Stalk-eyed Crustaceans of the Atlantic Coast of North America north of Cape Cod. Trans. Connecticut Acad., vol. v, Part I, May, 1879.

nearly as wide as the zoœcial apertures, smooth, shining, sometimes sculptured with raised lines, or with rounded sunken areas on the sides. A small oval disk on the lateral surfaces of the zoœcia. Avicularia small, with a rather short, thick, swollen head, the pedicel shorter than the vertical diameter of the head, attached to the distal end of the zoœcia.

East of George's Bank, 220 fathoms, on *Acanella Normani.* Presented to the U. S. Fish Commission by the captain and crew of the schooner "Alice G. Wunson."

ECHINODERMATA.

Solaster Earllii, sp. nov.

A large, handsome species. Arms nine in our specimen, elongated, tapering. Upper surface thickly covered with clusters of divergent spinules, mostly six to eight, much smaller and shorter than in *C. papposus.* Marginal plates large, prominent, the largest bearing about twenty spinules, in two transverse rows. Ventral plates with about seven or eight long acute spines in one transverse row. Adambulacral plates with about five shorter, more slender spines. Greatest diameter 180^{mm}; lesser 50^{mm}. Taken in lat. 43° 24′; long. 59° 46′, in 200 to 250 fathoms, by the schooner "Bessie W. Somers," and presented to the U. S. Fish Com. by Capt. Thomas F. Hayden.

Dedicated to Mr. R. E. Earll of the U. S. Fish Commission.

Molpadia turgida, sp. nov.

Body large, elongated, turgid, suddenly tapering posteriorly to the slender, moderately long caudal portion. Tentacles short, almost rudimentary, two-lobed, seldom expanded. Skin thin, often somewhat translucent, dark reddish or purplish brown, filled with perforated table-shaped or spinulated plates, and with numerous regular, circular and oval, biscuit-shaped orange-brown calcareous grains, of various sizes, less numerous than in *M. oölitica*, but far more numerous and more regular than in *M. borealis.* These grains have a concentric structure, either around one, or, when oval, around two nuclei. The perforated plates are rather large and irregular, but delicately formed, much less irregular and larger than in *M. borealis.* They usually have a central circle of three to six foramina, then a circle of ten or more, larger, oval foramina, separated by a thin framework, which runs out into irregular projections beyond the border; the central spinule is elongated, acute, consisting of three or four columns. The largest specimens are about 125^{mm} long, and 25 to 30^{mm} in diameter.

Bay of Fundy,—A. E. Verrill and S. I. Smith, 1865. Massachusetts Bay, 40–100 fath., soft mud, 1877, '78; Gulf of Maine, 1874; Casco Bay, 1873; off Nova Scotia, 1877,—U. S. Fish Commission. Gulf of St. Lawrence, Whiteaves.

ANTHOZOA.

Actinernus, gen. nov.

Body large, short, smooth. The margin below the tentacles is deeply divided into acute lobes, or teeth, continuous with the body-wall. The tentacles are rather large, and adnate to the marginal lobes for a considerable part of their length. Disk large, with the margin undulate or frilled in large specimens. The disk and tentacles apparently are not retractile.

Actinernus nobilis, sp. nov.

Body stout, with a very broad basal disk and short column, and toward the summit thrown into about eight large undulations or folds, bending outward and inward, corresponding to the lobes of the disk; the margin is deeply cut into sharp conical teeth, corresponding to the tentacles in number and position, and like them alternating in an inner and outer row; integument of column and teeth thick, firm and smooth. Tentacles numerous, elongated, tapering, acute, moderately large, subequal, in two rows close to the margin, adnate to the marginal teeth for about two-thirds of their length, or even more. Lips well-developed, with about eight large lobes on each side. Color, in recently preserved specimens, deep purplish brown on the disk and tentacles, with radiating lines of paler color on the disk; mouth deep brown inside; sides of body milk-white, with traces of orange-color where the outer coat remains.

Largest specimens, in alcohol, about four inches broad and three high. Four specimens were presented to the U. S. Fish Commission.

Off Sable I., N. S., 200–250 fathoms, Aug., and Banquereau, about 200 fathoms, Sept. 9, 1878,—Capt. J. W. Collins, sch. "Marion." Eastern slope of George's Bank, in about 220 fathoms,—Capt. and crew of the sch. "Alice G. Wunson," Sept., 1878. Lat. 42′ 31°; long. 64° 20′, 300 fathoms,—Capt. Wm. H. Greenleaf, sch. "Chester R. Lawrence."

Synanthus, gen. nov.

Actiniæ which have a broadly expanded, thin base from which new zoöids arise by budding, so as to constitute a small colony, connected together by a common base. Integument thin and smooth. Tentacles numerous, retractile.

Synanthus mirabilis, sp. nov.

Colonies often consist of five or six, or more, zooids, which are generally parasitic upon the branches of *Primnoa reseda* and *Paragorgia arborea*, often surrounding them like a ligature, and in the case of *Paragorgia* often forming deep constrictions so as to seriously weaken the branches. Column low and button-like in contraction, the integument so translucent as to show the numerous internal radiating lamellæ. Same localities as for the preceding species.

ART. LXII.—*On a new Absolute Galvanometer;* by N. D. C. HODGES.

IN the ordinary form of galvanometer the current is measured by the ratio of the force it exerts on the needle to the directive force of the earth, the ratio being determined by a measurement of the angle of deflection.

The moment of the force with which a unit current acts on the needle may be expressed in a series of the form

$$G_1 g_1 \sin\theta + G_2 g_2 \sin\theta\, Q_2'(\theta) + \text{etc.}$$

where G_1, G_2 are constants depending on the dimensions of the coil, and g_1, g_2 on those of the suspended apparatus, coil or magnet, as the case may be. $Q_1'(\theta)$, $Q_2'(\theta)$ are quantities varying with the deflection.

Only in case all the terms after the first may be neglected are the values of the current proportional to the tangents of the deflections. With a single coil this is not the case. By increasing the number of coils and suitably placing them, the magnetic field may be rendered more uniform.

In reading the deflection either a divided circle or a telescope and scale may be used. With the divided circle the deflection may be as great as 45°, but not more, or else the instrument would not be sensitive to changes in the current. The use of telescope and scale necessitates much smaller deflections. To regulate the strength of the current shunts of small resistance often have to be used; and the proportion of the current through the instrument is rendered doubtful.

If, instead of placing the plane of the coils parallel with the magnetic meridian, they are placed perpendicular to it, the sum of the force of the current and of the directive force of the earth would influence the magnet.

The formula $$\frac{t^2}{\pi^2} = \frac{K}{MT\,(1+\theta)}$$

expresses the relation between the time of vibration of a horizontal, swinging magnet, its moment of inertia K, its magnetic moment M, and the horizontal component of the earth's magnetic force T.

If this time, the time of vibration without the current, is first taken and then the time t, with the current, we get the relation between the two,

$$\frac{t_1^2}{\pi^2} = \frac{K}{M\,(T+F)\,(1+\theta)}$$

$$\frac{t^2}{t_1^2} = \frac{T+F}{T} \quad \text{or} \quad \frac{t^2 - t_1^2}{t_1^2} = \frac{F}{T}$$

when F is the directive force of the current on a magnet of unit magnetic moment.

The moment of the force F on the magnet is

$$C\,(G_1 g_1 \sin\theta + G_1 g_1 \sin\theta\, Q_1'(\theta) + \text{etc.})$$
$$= \sin\theta\, C\,(G_1 g_1 + G_2 g_2\, Q_1'(\theta) + \text{etc.})$$

θ=the angle between the axis of the coil and of the magnet.

Hence $$C\,(G_1 g_1 + G_2 g_2\, Q_1'(\theta) + \text{etc.}) = F.$$

For the small angles through which the magnet need vibrate, this factor may be considered constant and equals the constant of the instrument, used as a tangent galvanometer, when the deflection is supposed equal to 90°.

Let $G_1 g_1 + G_2 g_2\, Q_1'(0°) + \text{etc.} = K_{90°}$

Then $F = CK_{90°}$

The value of C is obtained in the form

$$C = \frac{t^2 - t_1^2}{t_1^2}\,\frac{T}{K_{90°}}$$

To find the value of $K_{90°}$ the same current, if passed through the instrument used as a tangent galvanometer, will give

$$C = \frac{T}{K\varphi}\tan\varphi$$

Hence $$\frac{T}{K\varphi}\tan\varphi = \frac{t^2 - t_1^2}{t_1^2}\,\frac{T}{K_{90}}$$

or $$K_{90} = \frac{(t^2 - t_1^2)\,K\varphi}{t_1^2 \tan\varphi}$$

If the value of K_ϕ is known for any value of φ, the deflection, the constant of the instrument used in this other way is given by this formula.

It is evident that the relative values of K_ϕ for different values of the deflection of a tangent galvanometer may be found by repeated application of this process.

$$K_{90} = \frac{t^2 - t_1^2}{t_1^2}\,\frac{K\varphi}{\tan\varphi}$$

$$K_{90} = \frac{t^2 - t_2^2}{t_2^2}\,\frac{K\varphi_1}{\tan\varphi_1}$$

$$\therefore \quad \frac{K\varphi}{K\varphi_1} = \frac{\tan\varphi}{\tan\varphi_1}\,\frac{t^2 - t_2^2}{t_2^2}, \frac{t_1^2}{t^2 - t_1^2}$$

Any of the usual methods for finding the constant of a galvanometer would also apply.

Physical Laboratory, Harvard College, Feb. 12, 1879.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a New Series of Molecules.*—In 1868, Angus Smith made an investigation into the absorption of gases by charcoal, believing that, since this action was on the border line between physics and chemistry, it would throw some light on chemical phenomena. The results then obtained showed that the gases were absorbed in whole volumes, hydrogen being 1, oxygen 7·99, carbonous oxide 6·03, carbon dioxide 22·05, marsh gas 10·01, nitrogen monoxide 12·90, sulphurous oxide 36·95, and nitrogen 4·27. The author has now taken up the subject anew and finds that charcoal does actually absorb gases in perfectly definite volumes, the physical action being like the chemical. Thus calling the volume of hydrogen absorbed 1, that of the oxygen is 8, the proportions by volume being the same as those by weight in chemical union. Moreover, since oxygen is 16 times heavier than hydrogen, charcoal absorbs 128 times more oxygen than hydrogen by weight. Now this number is exactly equal to the density of oxygen squared and divided by two, $\frac{16^2}{2}$, or it is half the product of the density of this gas and its atomic weight. Again, the most probable value for nitrogen is 4·66 volumes absorbed, and hence the weight absorbed is $14 \times 4{\cdot}66$ or 65·3. This number is $\frac{14^3}{3}$, since nitrogen is trivalent. Carbon dioxide is not divided but is simply 22^2. The carbonous oxide absorbed is 6 volumes, the carbon dioxide $6+16=22$ volumes, marsh gas $6+4=10$ volumes, nitrogen monoxide $8+4{\cdot}66=12{\cdot}66$ volumes. These figures seem to the author to suggest a new series of molecules, whose weights are produced by squaring the atomic weights and by certain divisions peculiar to the gases in question. It may be perhaps that the larger molecule exists in the free gas and is broken up on chemical combination. The building up of a molecule by volumes in this way suggests the possibility at least that our present molecules may be similarly constructed. — *Proc. Roy. Soc.*, Feb. 6, 1879. *Nature*, xix, 354, Feb. 1879. G. F. B.

2. *On the Reciprocal Displacement of Oxygen, Sulphur, and the Halogens, when combined with Hydrogen.*—Berthelot has studied the reciprocal displacements which take place in the so-called hydracids and finds that these also are regulated by the value of the heat of combination. Thus for example, experiment has given him the following equivalent numbers:

H+Cl	=HCl gas	+22·0	HCl dissolved	+39·3
H+Br gas	=HBr gas	+13·5	HBr dissolved	+33·5
H+I gas	=HI gas	—0·8	HI dissolved	+18·6
H+S gas	=HS gas	+3·6	HS dissolved	+ 5·8
H+O gas	=HO gas	+29·5	HO liquid	+34·5

From these numbers it follows: 1st, that Cl should displace Br and I, and Br should displace I, in the hydracids both when gaseous and in solution; this is common knowledge; 2d, that Cl and Br should displace S in hydrogen sulphide either gaseous or dissolved,—also a well known reaction; 3d, that I should displace sulphur in hydrogen sulphide in solution, forming HI dilute; but that S on the contrary should decompose gaseous HI, forming hydrogen sulphide. These facts were experimentally established by placing hydrogen sulphide in a sealed tube containing I, and heating to 500°; no reaction took place. But HI gas on the contrary reacts on S even in the cold, and if the tube be opened under water, the latter rises in the tube, remaining transparent till the inverse reaction takes place in solution, the iodine decomposing now the hydrogen sulphide again, with deposition of sulphur. 4th, that oxygen should displace S from hydrogen sulphide, a common reaction; 5th, that between chlorine and oxygen, an equilibrium should be produced, since on the one side gaseous chlorine should decompose water to form HCl in solution, and on the other gaseous oxygen should decompose dry HCl gas, to form water and chlorine. In proof of this, Berthelot mixed HCl and O in a sealed tube and passed sparks through the tube for several hours with the result, that nine-tenths of the HCl was decomposed, while a similar experiment with water vapor and Cl gave no result. 6th, that O should displace Br from HBr either gaseous or dissolved; and 7th, that oxygen should displace I, under the same circumstances, a fact well shown by the fact that a mixture of four volumes of HI and one of oxygen readily takes fire and burns with a red flame, a good lecture experiment. The inverse reaction does not take place.—*Bull. Soc. Ch.*, II, xxxi, 309, April, 1879. G. F. B.

3. *On the Liquefaction of Hydrogen Silicide.*—Ogier, in the laboratory of Berthelot, has prepared hydrogen silicide pure and has succeeded in liquefying it by means of the apparatus devised by Cailletet. At ordinary temperatures, about 10°, this gas sustained a pressure of 200 to 300 atmospheres without being liquefied. But on sudden expansion, even at fifty atmospheres, the cooling produces a thick mist and droplets appear on the walls of the tube. Under these conditions the gas is evidently very near its critical point. Indeed, cooling it only a few degrees below zero suffices to condense it totally. Under a pressure of fifty atmospheres it is liquid at $-11°$; of seventy atmospheres, at $-5°$; and of 100 atmospheres, at $-1°$. At zero, on the contrary, it remains gaseous even at 150 to 200 atmospheres. The critical point is therefore not far from zero.—*C. R.*, lxxxviii, 236, Feb. 1879. G. F. B.

4. *On the Ytterbia of Marignac, and on a New Element, Scandium.*—Nilson, who was on the point of commencing an investigation of the gadolinite and euxenite earths when Marignac's paper appeared, has proceeded with it since this chemist has given it up for want of material. Having 63 grams of erbia, the

molecular weight of which was 129·25, he sought at first to separate the ytterbia by a modification of Marignac's process, ceasing to heat the melted mass so soon as red fumes appeared. But it proved too tedious and he returned to the unmodified method. After thirteen series of decompositions of the nitrates by heat, there remained a basic nitrate which showed only feeble absorption bands in the green and red. The solution, precipitated with oxalic acid, was evaporated and gave 3·5 grams of a white earth with a scarcely perceptible rose tint, whose molecular weight was 127·64. This low number led the author to suspect the presence of a new element in the ytterbia, and a portion of the chloride was submitted to Thalén who found lines differing from any previously observed in this group. The earth was converted into nitrate, a suitable quantity of sulphuric acid was added, the solution was evaporated, finally over a naked fire, but at such a temperature that the residue dissolved perfectly in water. The molecular weight of the earth diminished gradually until it reached 105·83, and yet traces of ytterbia were present. Examined again spectroscopically by Thalén, it gave twenty-nine lines, the strongest of which had wave lengths of 6078·5, 6054, 6019, 5736, 5729, 5719, 5710·5, 5700, 5686, 5671, 5657·5, 5526, 5089, 5084·5, 5082·3, 4739, 4736·5, 4733. To the element thus established, Nilson gives the name *Scandium*, since the two minerals gadolinite and euxenite in which it occurs are of Scandinavian origin. Its oxide is a colorless earth, the solutions of which give no absorption bands. It is after calcination attacked with difficulty by dilute nitric acid, more readily by hydrochloric. Oxalic acid precipitates it completely. The nitrate is completely decomposed at a temperature at which ytterbium nitrate is only partially converted into a basic salt. Its sulphate is not changed at high temperatures, but is completely decomposed by calcination with ammonium carbonate. Calculated from ScO, the atomic weight cannot be far from 90; though if scandia be Sc_2O_3, the at. wt. would be 135.

The solutions from which the various basic nitrates had deposited were then submitted to examination. The result showed that while the molecular weight of the earth which had precipitated from the solution as basic nitrate continued to diminish, that of the earth which remained in solution remained constantly the same, about 131. Eight of the mother liquors gave a substance whose molecular weight was above 131. Treated again by Marignac's method eight times, these afforded 3·5 grams of an earth of a molecular weight of 131·63, the fused nitrate of which gave only a single feeble erbia absorption band in the green. Repeating the operation, the last traces of erbia were eliminated and the ytterbia obtained pure, its nitrate showing no absorption bands. The erbia of previous authors then is nearly all ytterbia and only a few per cent erbia. The author hopes to study erbia, ytterbia and scandia more carefully, since he has in conjunction with Clève, begun work on ten kilograms each of gadolinite and euxenite.—*C. R.*, lxxxviii, 642, 645, March, 1879. G. F. B.

5. *On an Amidonitrosulphide of Iron.*—DEMEL has repeated the experiment of acting upon a ferrous solution with potassium nitrite and ammonium sulphide, first noticed by Roussin, in order to study more carefully the product. To prepare the compound, 20 grams potassium nitrite is dissolved in 300 c. c. water, the solution is heated to boiling, 40 c. c. ordinary ammonium sulphide solution is added, and the heating continued for a few minutes. A solution of 33 grams crystallized ferrous sulphate in 200 c.c. water is then added gradually with shaking and the liquid boiled for ten minutes. It is then filtered and the filtrate deposits black needle-shaped crystals, which after recrystallization from water are obtained as brilliant black prisms. They decompose in the air, are easily soluble in water, alcohol and ether, evolve H_2S with dilute and brown vapors with strong HCl, and give off ammonia when boiled with KOH. Even below 100° this body decomposes, evolves heat and leaves ferrous sulphide. Analysis showed that the nitrogen was united partly to oxygen and partly to hydrogen, all the hydrogen being united to nitrogen. The numbers obtained gave the empirical formula $FeSN_2H_2O_2$, from which and the facts above given the rational formula must be $\begin{matrix} Fe\left\{\begin{matrix} NO_2 \\ SNH_2 \end{matrix}\right. \\ \| \\ Fe\left\{\begin{matrix} SNH_2 \\ NO_2 \end{matrix}\right. \end{matrix}$. Similar compounds with nickel, cobalt or manganese have not yet been obtained.—*Ber. Berl. Chem. Ges.*, xii, 461, March, 1879.

G. F. B.

6. *On a New Method of producing Ketones.*—VON BECHI has modified the method for preparing ketones originally suggested by Freund. In place of using zinc radicals, he employs iodides of the alcohol radicals in presence of sodium. In a dilute etherial solution of equal molecules of ethyl iodide and benzoyl chloride, well cooled, is placed the necessary quantity of sodium; at first no action is observable, but soon a yellow powder separates consisting of sodium iodide and chloride. After 48 hours, the whole is extracted with ether and the ether evaporated. A brown liquid is left, which washed with water and fractionated, distills between 205° and 210°, is a light yellow refractive oil of agreeable odor having the composition of phenylethylketone. The reaction is as follows:

$$\left\{\begin{matrix} C_6H_5 \\ COCl \end{matrix}\right. + \left\{\begin{matrix} C_2H_5 \\ I \end{matrix}\right. + Na_2 = NaI + NaCl + CO\left\{\begin{matrix} C_6H_5 \\ C_2H_5 \end{matrix}\right.$$

The method appears general.—*Ber. Berl. Chem. Ges.*, xii, 463, March, 1879.

G. F. B.

7. *On the Production of Aurin.*—CLERMONT and FROMMEL have succeeded in producing aurin directly by acting upon phenol by a mixture of carbonous oxide and oxygen in sealed tubes.

$$(C_6H_5OH)_2 + CO_2 = \left.\begin{matrix} C_6H_4OH \\ C_6H_4OH \end{matrix}\right\} C\left\{\begin{matrix} C_6H_4 \\ O \end{matrix}\right\}.$$

The CO_2 must be nascent to produce the effect.—*C. R.*, lxxxviii, 655, March, 1879.

G. F. B.

8. *Radiometer.*—In recent numbers of *Nature* (April 3rd and April 10th, 1879), Mr. W. CROOKES gives an abstract of his later researches on the "Repulsion resulting from Radiation." He first discusses the amount of repulsion produced by radiation on disks of various kinds and coated with different substances. The very delicate and ingenious apparatus, by which the repulsive forces were compared, is described at length; and the description shows what great skill has been acquired in controlling the obscure phenomena, which Mr. Crookes has so successfully elucidated. For details and numerical results we must refer to the original papers. The repulsions were measured both when no screen was interposed, and also when a cell of water was inserted in the path of the rays; and the difference in the relative effects under these conditions is very striking. These phenomena, which are similar to those first described by Melloni under the name of "Thermocrosis" are among the most interesting results of the investigation. In order to compare the two classes of results, it was first determined that the actual amount of repulsion on a lamp-blacked disk, when the water-screen was interposed, was only one-twelfth of that exerted by the standard candle flame when no screen was in the way, the distance of the candle and other things being of course equal. With the effect on the standard lamp-blacked disk the other repulsions were compared and hence if the direct effect of the source employed on this disk is arbitrarily expressed by the number 100, the effect of the same source on the same disk through the given water screen but under otherwise identical conditions, would be, according to the determination just referred to, expressed by the number 8·3. The other numbers of the following table have a similar meaning.

	No screen.	Water screen interposed.	Per cents with water screen.
Lampblack (standard disk), -----	100·	8·3	100·
Chromic oxide (pale green), -----	71·5	1·7	20·4
Copper tungstate, ----------	51·2	6·4	76·8
Prosulphocyanogen, ----------	43·9	1·0	12·0
Saffranin, ----------	41·0	4·3	51·6
Hydrated zinc oxide, ----------	40·5	1·2	14·4
Barium sulphate, ----------	37·4	0·3	3·6
Selenium precipitated, ----------	35·8	5·8	69·6
Copper oxalate, ----------	30·1	3·3	39 6
Calcium carbonate, ----------	28·5	0·3	3·6

It appears from this table that the substances experimented on may be divided into two classes.

(1.) Negative: those in which the repulsion behind water bears a *greater* proportion to the standard than when no screen is interposed.

(2.) Positive: those in which the repulsion behind water bears a *less* proportion to the standard, than when no screen is interposed.

Amongst Class 1, are copper tungstate, saffranin, selenium and copper oxalate. Amongst Class 2, chromic oxide, persulphocyanogen, hydrated zinc oxide, barium sulphate and calcium carbonate. Evidently these differences must correspond to a difference in the capacity of absorbing the luminous and the non-luminous

ultra red rays, or in other words to the thermocrosis of the several pigments employed.

As might be expected, the differences of qualities just described are brought out most strikingly when coatings of opposite classes are balanced against each other on the vanes of the movable fly of a radiometer, and this instrument can be constructed with a movable glass cap made tight by cement, so that the fly may be removed and the vanes shifted at pleasure. We quote from Mr. Crookes's paper the following description of the singular results he thus obtained.

"Disks coated on alternate sides with chromic oxide and precipitated selenium move in one direction to the naked flame of a candle and in the other direction when a water screen is interposed. With saffranin and hydrated zinc oxide, the instrument does not move at all when exposed to the naked flame, but revolves when a water screen is interposed. With thallic oxide and Magnus's green platinum salt, the instrument moves strongly when no screen is interposed, but is stopped with a water-screen. These results are all in conformity with the figures."

"A pith radiometer coated with precipitated selenium and chromic oxide was exposed to the radiation from a colorless gas flame of a Bunsen burner, and also to the same colored intensely green by thallium. To the eye, by this light, the chromic oxide looked nearly white and the selenium black. The rotation due to the repulsion of the chromic oxide was however apparently as strong as when the non-luminous flame was used. This experiment proves that certain substances have an opposite absorptive action on rays of dark heat to what they have on light, and that an optically white body may be thermically black, and vice versa. In this case, for instance, chromic oxide was optically green and thermically black, while scarlet selenium was thermically white and optically black."

It was originally thought that a slice of tourmaline, being black to a ray of light polarized in one plane and white to a ray polarized in the other plane, would be repelled when the incident light was quenched by it, and not affected when the incident light passed through it. Mr. Crookes's measurements, however, show that this action does not exist to any appreciable degree. He experimented on a plate of tourmaline suspended in vacuo on a torsion balance, and measured the amount of repulsion produced by a beam of polarized light when in different planes, and he explains the negative results by saying that while the repulsion resulting from radiation is almost entirely a surface action, the action of a tourmaline on a polarizer is one in which thickness is necessary.

The analysis which Mr. Crookes next gives of the effect of the shape of the vanes of a radiometer in influencing the amount and direction of repulsion is very ingenious, and highly interesting; but the discussion cannot be made intelligible without the numerous figures with which the papers are illustrated. It is sufficient to say that the effects are shown to be in accordance with the

theory which Mr. Crookes has so fully worked out. One of the most remarkable of these effects is that produced by the viscosity of air which at a rarefaction of 129 millionths of an atmosphere, appears to be only a little less than its viscosity at the normal density, and hence the vanes of a radiometer at a speed of 100 revolutions a minute exert a considerable drag on a disk of mica rotating just above them.

In reading these very interesting papers one is greatly impressed by the perfection to which the mercury pump, and the means of measuring the degree of exhaustion which the pump produces, has been brought. In some of his experiments Mr. Crookes speaks of carrying the exhaustion to four ten-millionths of an atmosphere, and we quote as follows from the close of his article.

"In concluding this abstract of my researches on Repulsion resulting from Radiation I cannot refrain from pointing out how erroneous the ordinary ideas of a 'vacuum' are. Formerly an air pump which would diminish the volume of air in the receiver one thousand times was said to produce a vacuum. Later a 'perfect vacuum' was said to be produced by chemical absorption, and by the Sprengel pump, the test being that electricity would not pass; this point being reached when the air is rarefied one hundred thousand times. Now Mr. Johnston Stony has calculated that the number of molecules in a cubic centimeter of air at the ordinary pressure is probably something like one thousand trillions. When this number is divided by 2,500,000 there are still four hundred billion molecules in every cubic centimeter of gas at the highest exhaustion to which I carried the experiment, a rarefaction which would correspond to the density of the atmosphere about seventy-five miles above the earth's surface, that is, if its density decreases in geometrical progression as its height increases in arithmetical progression. Four hundred billion molecules in a cubic centimeter appear a sufficiently large number to justify the supposition that when set into vibration by a white hot wire they may be capable of exerting an enormous mechanical effect."

9. *The Magic Mirrors of Japan.*—The bronze mirrors of Japan are usually circular, from three to twelve inches in diameter, made of bronze, and with a bronze handle covered with bamboo. The reflecting face is generally more or less convex, polished with a mercury amalgam and the back is ornamented with a varied design. The magic property, which is only possessed by a few rare specimens, appears when a bright beam of light is reflected by the polished surface on to a screen. There is then seen on the screen an image formed of bright lines on a dark ground more or less perfectly representing the pattern on the back of the mirror, although not only is the latter wholly hidden from the light but also the polished surface itself, if looked at directly, acts like an ordinary mirror reflecting the objects in front of it, and giving no indications whatever of the raised patterns on the back. In the "Friday evening discourse at the Royal Institution" of Jan. 24, reported in *Nature* of April 10th, Prof. W. E. Ayrton gives a full

and satisfactory explanation of this remarkable effect, which so far from being intentional on the part of the manufacturers of the mirrors, appears to have been quite unknown to the Japanese, although known to the Chinese from the earliest times. It appeared from the experiments of Professor Ayrton that: 1, when a divergent beam of light fell on the mirror the pattern appeared as bright on a dark ground; 2, when the beam was parallel the pattern was invisible; 3, when the beam was convergent the pattern appeared as dark on a light ground. These and similar experiments exhibited by the lecturer all point to the conclusion that the effect is caused by inequalities in the curvature of the reflecting surface corresponding to the raised pattern on the back, the portions where the relief increases the thickness of the plate being flatter than the remaining convex surface, and even being sometimes actually concave. Professor Ayrton fully describes how such an irregular form would result from the peculiar mode by which the Japanese produce the polished surfaces; whenever the bronze casting is thus worked sufficiently thin to determine a "buckling" of the metal. This result is very exceptional. No thick mirror reflects the pattern on the back, and not more than two or three per cent of the ordinary Japanese bronze mirrors show the magic property clearly. J. P. C., JR.

II. Geology and Mineralogy.

1. *The Cincinnati Group.*—A committee was recently appointed by the Cincinnati Society of Natural History to consider "questions of geological nomenclature," and especially the propriety of using the term "Cincinnati Group," as first proposed by Meek, for the Hudson River Group, and the age of the Lower Silurian rocks of Southwestern Ohio, Southeastern Indiana and Kentucky. The following are extracts from this very satisfactory report.

"The fossils found in the strata, for twenty feet or more above low water mark of the Ohio river, in the first ward of the city of Cincinnati, and on Crawfish creek, in the eastern part of the city, and in Taylor's creek, east of Newport, Kentucky, at an elevation of more than fifty feet above low water mark in the Ohio river, indicate the age of the Utica Slate Group of New York. A fauna is represented in these rocks that is not found above or below them. Within this range we find the *Triarthus Beckii*, *Leperditia Byrnesi*, *Leptobolus lepis*, *Buthotrephis ramulosa*, and several species of Graptolites, Crinoids, Bryozoans and Brachiopods, that seem to be confined within its limits. * * *

"Above the range of the *Triarthus Beckii*, the fossils, as well as the position of the rocks, indicate the age of the Hudson River Group of New York, and we have no hesitation in so referring them, and entertain no doubt of the correctness of the reference. * * *

"In Southeastern Indiana neither the Trenton nor Utica slate appear, and, consequently, we refer all the Lower Silurian rocks of that State to the Hudson River Group.

"The Trenton Group is not exposed at Cincinnati, nor at any point in Ohio west of the city, but we think it is probable that it may be represented in the banks of the Ohio river a few miles east of the city. The Utica Slate is represented in Ohio only in the banks of the river, at the city of Cincinnati, and east of the city, and in the excavations near the mouths of the streams which enter the river east of the city. Consequently all the Lower Silurian rocks in Southwestern Ohio belong to the Hudson River Group, except those represented by the small exposures in the banks of the river at Cincinnati, and east of the city, in the immediate vicinity of the river.

"The conclusion to which we have come is, that all the Lower Silurian rocks which we have had under consideration, are to be referred to the Trenton, Utica Slate and Hudson River Groups, and that the name 'Cincinnati Group' should be dropped, not only because it is a synonym, but because its retention can subserve no useful purpose in the science, and because it will, in the future, as in the past, lead to erroneous views and fruitless discussion. And we would add that so far as any investigations of these rocks have been made, they have not led to any other or further subdivisions than those which we have adopted, and which have been so thoroughly and firmly established by the geologists of the State of New York."—Signed: S. A. Miller, Fred Braun, Jno. Mickleborough, John W. Hall, Jr., E. O. Ulrich, A. G. Wetherby, Geo. W. Harper, Paul Mohr, C. B. Dyer, R. M. Byrnes.

This Report, besides appearing in the publications of the Cincinnati Society, is also published in the tenth Annual Report of the Geological Survey of Indiana, where it is followed by a long list of the fossils found over the region referred to, in the Hudson River, Utica Slate and Trenton Groups, by S. A. Miller of Cincinnati.

2. *Atlas to the Coal Flora of Pennsylvania, and of Carboniferous Formations throughout the United States;* by Leo Lesquereux. Second Geological Survey of Pennsylvania.—This atlas by Mr. Lesquereux is a volume of eighty-seven plates, issued in advance of the volume of descriptive text. The plates are of remarkable beauty and perfection. The drawings were prepared with great care and the engraving is excellent. To Mr. Lesquereux, the author, and to Professor Lesley and the Geological Commissioners of Pennsylvania, who have had the volume published in such admirable style, the thanks of all friends of paleontological botany, the world over, will be given without stint. The work at once becomes the necessary hand-book for all who would study American coal plants. The atlas contains figures of 260 species which have been named and described by Mr. Lesquereux, and of these 122 are now for the first time figured.

Of his modifications of classification—such as his new genus Pseudopecopteris—we can better judge when the volume of text is received. Over thirty species of *Neuropteris* are figured, and more than twenty of Pecopteris, and the whole department of

fossil botany receives new illustrations from American specimens. Much light is thrown upon the Cordaites group, a class of Carboniferous plants hitherto a great puzzle to botanists. We shall notice this rich contribution to science more in detail when we have received the volume of descriptions.

3. *Materialien zur Mineralogie Russland, von Nikolai von Kokscharow.* Vol. viii, pp. 177–384, vol. ix, pp. 1–32.—Mineralogists will welcome an addition to the great work of Professor Kokscharof on the Mineralogy of Russia; the seventh volume is thus completed and an eighth commenced. The description of the crystalline form of each species considered is marked by the same accuracy and thoroughness that has characterized the work from the beginning. The following are the more important species described: Breunerite; pyrite; species of the mica group; waluewite (a new species near xanthophyllite); perofskite; eudialyte.

4. *Neues Jahrbuch für Mineralogie, Geologie and Paleontologie.*—The long known and highly valued Jahrbuch für Mineralogie, etc., has passed into the hands of a new corps of editors: Professor E. W. Benecke, in Strassburg, will have charge of the Geology and Paleontology; Prof. C. Klein, in Göttingen, of the Mineralogy; and Prof. H. Rosenbusch, in Heidelberg, of the Lithology. The first number under these editors has just appeared, (drittes u. viertes Heft, 1879). It contains a large number of original articles, and with the correspondence and extracts of papers in the different departments, covers 255 pages. The many workers in science who have used the Jahrbuch in years past, will wish for it a long-continued career of usefulness.

5. *Brief notices of some recently described Minerals:—Huntilite.* Described by Prof. Henry Wurtz, as occurring in two varieties. The most abundant variety is amorphous, often porous and crumbly, dark slate-gray, or almost black in color, and entirely dull in luster. The other kind has a lighter slate-color, a crystalline structure, and probably one cleavage; it is intimately associated with calcite. The hardness is 2·5; the streak is bronze-color; the mineral is sub-malleable. Analyses of the two kinds gave the following results:

1. Amorphous. 2. Crystallized.

	As	Sb	S	Hg	Ag	Co	Ni	Fe	Zn	H_2O	gangue.	
1.	21·10	3·33	0·78	1·04	59·00	3·92	1·96	3·06	2·42	0·19	3·23	=100·03 G.=7·47
2.	23·99	4·25	1·81	1·11	44·67	7·33	2·11	8·53	3·05	0·33	1·65	= 98·83 G.=6·27

The mercury is believed to be present as amalgam; the sulphur as pyrite; after the deduction of these, the following ratios are obtained, the arsenic and antimony being taken together, and all the metals combined, according to their quantivalences:—$As : \frac{I}{R} =$ 1:2·90 (amorphous) and =1:2·99 (crystalline). The general formula $AsAg_2$ is proposed, but the results of the analyses would suggest grave doubts as to the homogeneity of the material examined. Found at the Silver Islet Mine, Lake Superior. Named after Dr. T. Sterry Hunt.—*Engineer. and Mining J.*, Jan. 25, 1879.

Animikite. Announced provisionally by Prof. Wurtz. It occurs sometimes in incrustations over masses of huntilite; also in large isolated plates or slabs. Specific gravity =9·45. Color white or grayish-white. Fracture fine granular, conchoidal. An analysis gives: Sb 11·18, As ·35, S 1·49, Hg ·99, Ag 77·58, Co 2·10, Ni 1·90, Fe 1·68, Zn 0·30, gangue 1·68=99·31. Found at the Silver Islet Mine, Lake Superior. Named from the Indian word *animikie*, meaning *thunder*, whence Thunder-Bay. — *Ibid.*, Feb. 22.

Randite. Occurs as a lemon-yellow incrustation on granite from Philadelphia. Earthy, probably crystalline. Hardness =2·3. An analysis upon ·047 gr. gave:—CaO 32·50, U_2O_3 31·63, H_2O 6·53, (CO_2 29·34 by difference) =100. The formula deduced is $Ca_5U_2C_6O_{20}+3H_2O$, which, in case it is confirmed by further examination, would place it near liebigite. Named after Mr. Theodore D. Rand, of Philadelphia. — *Proc. Acad. Nat. Sci. Philadelphia*, 1878, 408.

Hannayite, Newberyite. Two new phosphates from the guano of the Skipton Caves, Victoria, described by vom Rath. Hannayite crystallizes in the triclinic system; cleavage basal perfect, less perfect parallel to the two prismatic planes. Specific gravity =1·893. The mean of two analyses gave: P_2O_5 45·70, MgO 18·90, Ammonia 8·09, H_2O 28·20=100·89. The loss of water between 100° and 120° is 21·08 per cent.

Newberyite crystallizes in the orthorhombic system. The cleavage is brachdiagonal perfect, also basal imperfect. An analysis gave: P_2O_5 41·25, (MgO 23·02 by difference), H_2O 35·73=100·00. The formula deduced is $Mg_2P_2O_7+7aq$.—*Bull. Soc. Min. France*, 1879, 79.

III. Botany and Zoology.

1. *Catalogue of the Davenport Herbarium of North American Ferns, Massachusetts Horticultural Society;* by George E. Davenport. Salem, 1879. 8vo, pp. v, 42.—This is a very full catalogue of the known Ferns of the United States and British America, and contains the names of collectors and donors, and the localities of all the North American ferns in the very rich collection which Mr. Davenport has presented to the Massachusetts Horticultural Society. The genera and species are arranged very nearly in the same order as that of Mr. Robinson's check-list, and that is based on the system of Mettenius. The Catalogue contains the names of 32 genera and 142 species, all but one or two of which are represented in the Herbarium by North American specimens. A good many excellent notes on critical forms are scattered through the book, and no student of our Ferns can afford to neglect its pages. *Pteris serrulata* appears here for the first time as a North American species, having been discovered growing spontaneously in the vicinity of Mobile, Alabama, by Mr. Charles Mohr of that city. *Polypodium pectinatum* and *Adiantum tenerum* are also for the first time announced as Ferns

of the United States. Specimens of the former, the name of which had not been definitely settled, had been sent to Mr. Chas. E. Faxon to draw for the *Ferns of North America*, and that gentleman noticed the difference between them and his own specimens of *P. Plumula.* He brought the matter to the attention of the writer of this notice, who then decided to call the large form *P. pectinatum* Linn., and the smaller one *P. Plumula.* The *Adiantum* had been for a year or more in the hands of Mr. Davenport and Mr. Faxon, as unchallenged *A. Capillus-Veneris*, and was first pronounced something different from that species by Mrs. Dr. Barnes, of Syracuse, who obtained fronds from living plants brought from Ocala, Florida, by Mr. Christian Beh, in March, 1877.

Mr. Davenport retains *Pellæa brachyptera*, of Baker, as a distinct species, and is no doubt right in doing so. Within the last few years it has been sent in by many collectors, and keeps its distinctive characters even better than some other recognized Californian Ferns. *Aspidium Bootii* of Tuckerman, is maintained as a distinct species, and so is *A. Americanum*, of Davenport, the *A. spinulosum* var. *intermedium* of Gray's manual.

An appendix gives a list of doubtful and excluded species, and one introduced species, *Adiantum cuneatum*, which was found "Established at Valley Falls, Rhode Island" by Mr. J. L. Bennett, who will doubtless give full particulars of his discovery in his forthcoming "*Plants of Rhode Island.*" [It seems hardly worth while to introduce into a work like this a mere escape from cultivation, doubtless transient.] The Catalogue is beautifully printed, and contains very few typographical or other errors to mar its excellence. D. C. E.

2. *Cane-sugar in Early Amber Cane.*—Professor Gœssmann (Fifteenth Annual Report of Mass. Agricul. College) comes to the following conclusions respecting the proportions of cane and grape-sugar in this variety of Sorghum at different periods of its growth: 1st. Grape-sugar appears in the cane at an early stage of its growth, and increases slowly to from three to four per cent before cane-sugar is formed; 2d. Cane-sugar is first noticeable at the time when the flower stalks become visible above the leaves, and its amount increases steadily until the seeds are of full size, yet still soft; 3d. The relative proportion of grape-sugar to cane-sugar at any time before the hardening of the seeds, do not exceed 3·16 per cent of the former to 8·49 per cent of the latter, in the majority of cases it was about three to seven. G. L. G.

3. *Number of the digestive glands in Dionæa.*—Léo Errera, thinking it would be physiologically interesting to know the number of glands to each flytrap of *Dionæa*, made a careful examination in this regard. He found an average of sixty to each square millimeter, or about 8,000 to each leaf. See Comptes-Rendus des Sèances de la Soc. Roy. Bot. de Belgique, April, 1879, p. 56. A. G.

4. *Characeæ Americanæ, Illustrated and Described by* Timothy F. Allen, A.M., M.D., etc.—This work is published by

the author himself, in very handsome style, each part consisting of one leaf or page of letter-press and a plate, in quarto form. The plate is printed in green color. The second fascicle has also a wood-cut in the letter-press. It is evident that Dr. Allen is making this a labor of love, regardless of expense. He announces that his work "will be issued each month, and will include every species and variety known to American waters. The author will be happy to send the work to botanists and receive in return the *Characeæ* of their collecting, to the number of fifty specimens of each variety." Directions for collecting and preparing specimens of *Charæ* are appended to the announcement on the cover. Each plate gives a view of a specimen in the natural size, a fructiferous portion magnified, and a cross-section of stem. The general view of the plant is particularly good. The magnified portions have a certain stiffness and solidity, which will probably be got rid of in future trials. Dr. Allen should be, and we may be sure will be, encouraged to carry on to completion an undertaking which will make an obscure and neglected branch of botany popular in this country, and which may incite to new discoveries. A. G.

5. *Malesia; Raccolta di Osservazionie Botaniche interno alle Piante Dell' Archipelago Indo-Malese e Papuano, da* ODARDO BECCARI. Vol. I, fasc. 1–3. 1877–78. 256 pp. tab. I–XV, 4to. Geneva.—Dr. Beccari, the successful explorer of New Guinea, Borneo, etc., and now the Director of the Royal Museum at Florence, is publishing in this fine work his botanical discoveries and those of Signor D'Albertis as fast and as far as he is able to elaborate them. Thus far the articles are all by his own hand; and the work bids fair to be one of the most important of recent contributions to systematic botany. It is not often that we can have such an interesting accession to Phænogamous Botany as is Beccari's *Corsia ornata*, a small root-parasitic plant of New Guinea (dedicated to the Marquis Corsi Salviati), which may be speculatively viewed as a sort of survival, representing a type from which *Orchideæ* and *Burmaniaceæ* have proceeded. The 6-phyllous perianth has five similar and lorate divisions, and a sixth much larger and dilated one which bears a nectary within; but this is the posterior one of the outer series. The androecium has its full compliment of six wholly normal and similar antheriferous stamens, with the inner series of these the three carpels of of the ovary normally alternate; and the large placentæ are carried inward on imperfect dissepiments, thence their lamellæ are revolute toward the back of the cells.

The first fascicle is devoted to Palms; the second to these and to *Icacineæ*, *Menispermaceæ*, *Monimiaceæ*, etc.; with new genera in all; the third has an excursus on *Nepenthes* and its distribution, and describes new *Burmanniaceæ*. A. G.

6. *On the Self-fertilization of Plants;* by the Rev. GEORGE HENSLOW, M.A., F.L.S., etc. A memoir in the Transactions of the Linnean Society of London, ser. 2, Bot. vol. i. pp. 318–398, with a plate. Read Nov. 1, 1877. Issued 1879.—This paper is

elaborate, mostly able as well as ingenious, in all respects considerable, and unconvincing. Its thesis is, the Darwinian "Nature abhors perpetual self-fertilization," read backward. It concludes that, "not only are the majority of plants self-fertilizing, but that those which are exclusively so propagate abundantly and with extraordinary rapidity, are best able to establish themselves in foreign countries, as, being quite independent of insects, they run no risk of extermination on that score; . . . that, so far from there being any necessarily injurious or evil effects resulting from the self-fertilization of plants in a state of nature, they have proved themselves to be in every way the best fitted to survive in the great struggle for life." The hypothesis is also advanced "that they are all degraded forms," and that *therefore* "their ancestral life-history is a longer one than that of their more conspicuous and intercrossing relations." We fail to see how this follows, except upon the assumption that the earliest phænogamous plants had the most highly organized blossoms; and that would not accord with vegetable paleontology.

Mr. Henslow rejoices that he has one staunch supporter; "for, as has been seen, Mr. T. Meehan has arrived at the same conclusion;" and indeed he builds not a little upon facts supplied by Mr. Meehan's observations. He cites the latter's "admirable paper, which was reproduced in the 'Gardner's Chronicle' for Sept. 11, 1875, and is in fact an 'apology' for self-fertilization." As he then marshalls twenty reasons for believing particular plants to be normally self-fertilizing, and nineteen "chief facts which may be regarded as occurring correlatively with self-fertilization, some being actual causes which directly or indirectly bring it about," it would appear that it is no longer self-fertilization, but rather the existence and *raison d'être* of cross-fertilization that stands in need of apology, or of explanation.

He freely concedes that the flowers of many plants, and some whole orders, are so constructed that intercrossing is for them a necessity; also that most of those which are believed "to be normally self-fertilizing" because they can and do fertilize themselves habitually," yet "may in some cases be cross-fertilized by insects." It is admitted that the structure of the latter is *adapted*—most variously and wondrously adapted—to being fertilized by particular insects. As this comes to pass in plants and flowers of the highest organization and greatest specialization, Darwin and his school conclude that this is a most advantageous outcome, and means some real good to the species; that when this is accompanied with a loss of self-fertility, it is the loss of something no longer useful, something better than self-fertility having taken its place. But Mr. Henslow, reading this the other way, having determined "that self-fertilization is *per se* a decided advantage," and free from injurious liability, comes to regard intercrossing as merely "a compensatory process for the loss of self-fertility."

But how and why did this "compensatory process come to

pass? It is conceived on both sides that flowers were "primordially inconspicuous." (To this Henslow adds hermaphrodite and self-fertile, but that need not here come into account.) Both agree that insects have mainly determined their conspicuousness. Darwin says this has been determined through natural selection by the survival of the more and more conspicuous variations, correlated with their producing something good for the insect of which the coloration was a sign, and that the preferential survival of the more showy and attractive was a consequence of some benefit of the intercrossing. Henslow propounds the view that insects have determined the conspicuousness more directly, and not by benefiting but by irritating the flowers. "These, by being greatly stimulated by the repeated visits of insects, tend to become hypertrophied. Hence the corolla enlarges, becomes more brightly colored, the nectariferous organs increase the quantity of secretion, and the stamens develope more pollen. Such being the case, nourishment is withheld from the pistil, which is delayed in its development; consequently such a flower is very generally proterandrous." Mr. Darwin might accept this as an ingenious conception of the way the specialization comes about, still insisting on the advantage of the resulting intercrossing—" or else the thing would hardly come to pass," as the poet has it. And Mr. Henslow's hypothesis has to be supplemented to account for proterogyny, which is not much less common. But Henslow's supposed process works evil instead of good, and is therefore utterly anti-Darwinian and "dysteleological." For the result is a disturbance of the equilibrium and proper correlation between the andrœcium and gynœcium; and this, carried further, should upon this view result in the monœcious and diœcious states. So, accordingly, the cross-fertilization which comes into play in the case of separated sexes, and in that of self-sterile hermaphroditism, is not for any good there is in it *per se*, but because it may no better be. And all the elaborate, exquisite, and wonderfully various modes of adaptation of flowers to insects are only ways of repairing the damages inflicted upon blossoms by insects through their persistent visits! Did Mr. Henslow ever ask himself the question why the sexes are separate in animals?

The conclusion which Mr. Darwin had helped us to reach is, that intercrossing should be regarded as the aim in nature and on the whole most beneficial, and self-fertilization as a safe-guard against the risks of crossing; that most hermaphrodite flowers have the advantage of both, the latter for immediate sureness, the former for ultimate benefit. Upon the new view, self-fertilization is the aim and the consummation, and cross-fertilization at best a succedaneum. By it insects may repair the damage they have caused to blossoms through endowing them with "the fatal gift of beauty," and stimulating their organs of secretion; and by it the winds may bring chance relief to those which, at length abandoned by their spoilers, have lost this attractiveness and fallen to the degradation of unisexuality. For these last, as has

already been stated, are hypothetically regarded as degraded from higher floral types.

We are bound to glance at some of the considerations which are adduced in support of this thesis. They are multifarious and of unequal value. As has occurred in other cases, so here also, the weightiest objections to Mr. Darwin's view are those which he has himself brought out, namely, the fact that, as tested experimentally under cultivation, while some plants are much increased in vigor and fertility by artificial intercrossing, others are not sensibly benefited; and that the benefit derived in marked cases is not cumulative, but reaches its maximum in two or three generations. And even close breeding under cultivation occasionally gives rise to very vigorous and fully prolific self-fertile races. Then many plants are fully self-fertile in nature, and it is not proved that any such have lost or are in the way of losing either fertility or vigor through continued inter-breeding. But, before drawing from this the conclusion that cross-fertilization is of little or no account in nature, it should be remembered that bud-propagated races are in similar case. Races exist which have been propagated only from buds for hundreds of years, with seemingly undiminished vigor, and there is no proof that any one has succumbed under the process. But for all that we do not doubt that sexual reproduction contributes something to the well-being of the species, besides facilitating its dispersion. Again, no one questions the necessity of fertilization by pollen to the production of embryo in the seed; yet, even in this, the necessity is not so imminent but that some embryos may originate without it. (See preceding volume of this Journal, p. 334.)

In short, the facts brought out by Darwin and others, and all the considerations of the present essay, are best harmonized by the conception which the former has consistently maintained, namely, that an occasional cross suffices to secure the benefit of intercrossing, whatever that may be. Nothing yet appears which seriously disturbs our conviction that just this is what nature generally provides for.

Mr. Henslow's proposition, "The majority of flowers are self-fertile," is doubtless true in the sense that they are capable of self-fertilization, and is not improbable in the sense that they "can and do fertilize themselves habitually." But his inference that the majority of flowers, or that any flowers, actually propagate for a series of generations by self-fecundation, or that a cross if it occur is "exceptional," and of no account, is surely unwarranted by the evidence which he has adduced.

Occasionally the reported facts will not bear scrutiny. *Gentiana Andrewsii*, it is said, never opens at all in America. It opens in sunshine in the middle of the day here in New England. And while looking at closed flowers we have seen a humble bee emerge from one. We have, in this Journal, shown how it is that self-fertilization is impossible during the first three or four days of anthesis, but neatly practicable afterwards. It is rash to

infer (as on p. 330) that papilionaceous flowers which shed their pollen early in proximity to the stigma are therefore self-fertilized. In most of the cases adduced the pollen is not lodged upon the stigma, but upon the style below it, and the adaptations for intercrossing, though the mechanism be different, are as explicit as in the analogous case of Campanula. "Fremont pathetically describes the solitary bee that rested on his shoulder at the top of Pike's Peak." The pathos is wasted as respects all but this particular bee; for the entomologists find the alpine region of the Rocky Mountains to be as well stocked with flying insects as are alpine regions in other parts of the world. They do not superabound, but if from the alpine flora we subtract the evidently entomophilous and the anemophilous blossoms, the remainder will be nearly nil. And as to the correlation of this comparative scarcity of insects with the marked conspicuousness of blossoms, this is the way the lesson is read by a most eminent physiologist: "Even the glowing hue of alpine flowers is accounted for by the attraction which brighter-colored individuals exercise upon the insects, scarce in those heights and necessary for fertilization."

One or two of the author's own observations are perhaps to be revised. "*Gaura parviflora* . . . has no corolla and is cleistogamous, in that it is self-fertilizing in bud, as I found in specimens growing at Kew." Were they not imperfectly developed blossoms, perhaps late in the season? Here the flowers open freely and have rose-colored petals. If he will examine fresh specimens of *Scrophularia*, it will soon be clear that his idea of their self-fertilization (p. 371) is a mistake. It is a mere slip in the Genera Plantarum through which abortive stamens are attributed to the cleistgamous flowers of *Epiphegus*. The authors evidently meant to describe the case just as Mr. Henslow found it to be, but used a wrong word.

"Weeds are probably all self-fertilizing or anemophilous. A weed is simply an unattractive plant, and possessing no feature worthy of cultivation." It may be as difficult to define "a weed" as to define "dirt." But, turning to the Handbook of the British Flora, we find, as we expected, that the showy Corn Poppy, Cockle, and Larkspur are denominated weeds. Why weeds should possess the vigor and gain the predominance which they do is a large question, to which other solutions have been offered than that the one which is in this essay very plausibly maintained. We cannot take up the topic here; but, without acceding to his general proposition, we are much disposed to agree with the author in this essay, as respects some of them, that aptitude for self-fertilization may have given them the advantage which has determined their wide dispersion.

The insistence upon the importance of self-fertilization is what gives this essay its value. As a whole it fortifies the proposition, well laid down by Herman Mueller, which Mr. Henslow cites:— "that, under certain conditions, the facility for self-fertilization is most advantageous to a plant, while, under other conditions, the

inevitableness of cross-fertilization by the visits of insects is the more advantageous." But this is not our author's thesis. It comes to this: the plan of nature is either cross-fertilization supplemented by close-fertilization, or close-fertilization tempered by cross-fertilization. As restricted to plants the difference is not wide. Regarded generally, the Darwinian axiom is still best sustained. A. G.

7. *On the causes of the change in form of Etiolated Plants;* by Professor GODLEWSKI, Dublany (Poland). Bot. Zeit. 6, 1879. —In 1873, Professor Godlewski published in Flora an account of his investigations respecting the formation of starch in chlorophyl grains. In that memoir he stated that the changes in form which plants undergo in darkness are not due to the suspension of the assimilative process. In 1875 and 1877 he published in the Polish language two short notices of his further observations upon this subject, and which he now fully recounts in the present paper. Only the first series of his later experiments will be referred to now, namely, those bearing upon the question as to the relation of the assimilative process to the change of form in growing plants deprived of light. It is a general rule, to which there are some exceptions, that internodes grown in the dark are longer, and leaves are smaller than those which develope in sunlight. In Pringsheim's Jahrbücher f. wiss. Botanik, vol. vii, p. 213, Dr. G. Kraus has sought to explain the latter fact by the hypothesis that it is chiefly out of assimilated matter freshly formed in growing green leaves themselves that they expand to their full size, and hence the diminutive size of etiolated leaves is thought by him to be directly dependent upon the absence of the assimilative process.

In Professor Godlewski's experiments germinating plants were cultivated in an atmosphere deprived of its carbonic acid, some of them in light, others in perfect darkness, but under similar conditions of temperature and moisture. It was found that when the plantlets had exhausted the food stored in the seed, and had ceased to grow, the total weight of dry organic matter was the same in the green and in the etiolated plants. The plantlets which had grown in the light but in air free from carbonic acid, and where assimilation could not take place, did not bear the slightest resemblance in form to etiolated plants. They were of perfectly normal habit. G. L. G.

IV. ASTRONOMY.

1. *Orbits of the binary systems, μ Herculis and* 298 *Struve;* by W. BEEBE.—The double star μ Herculis had been observed since 1858, and has shown a change of about 180° in the position angle though the observations, twenty-eight in number, and by twelve different observers, exhibit large discrepancies and are not all trustworthy.

The orbit was computed by Herschel's first method and agrees with the interpolation curve quite closely. The corrections to E,

T and P., obtained by Klinkerfue's first method did not, however, improve the agreement. The eccentricity is somewhat uncertain and the periodic time probably too large. The observations for 298 of O. Struve's catalogue are thirteen in number and agree tolerably well. It has been observed since 1843, and the position angle up to 1878 had changed about 130°. The orbit was computed by Herschel's second and Klinkerfue's first method. The orbit however is not definitive.

For the observed places used I am indebted to Mr. Burnham, who kindly collected for me all the available material.

	μ Herculis.	298 O Σ.
T	1873·4	1881·7
P	225· years	79·2
Ω	34°	5° 58′
π-Ω	143° 52′	357 17
i	37 10	66 35
e	·731	·585
a	2″·69	1″·23

New Haven, April 5th.

2. *Report of the Observations of the Total Solar Eclipse, July 29, 1878, made at Fort Worth, Texas.* Edited by LEONARD WALDO, Assistant at the Observatory of Harvard College. 60 pp. 4to, with 4 plates.—The Fort Worth Eclipse party consisted of Messrs. Waldo, Willson, Rees, Pulsifer and Seagrave, a volunteer party whose special object it was to record such phenomena as might aid in establishing the correct theory regarding the solar corona. Observations were made with the naked eye, the telescope, the spectroscope, the polariscope, and photographs of the corona were taken both with and without double refracting prisms. Professor Pickering and Mr. Waldo consider that the double image photographs imply tangential polarization of the light of the corona.

Mr. Pulsifer observed the reversal of the lines of the spectrum with the bright lines (except C) shortened at each end. He infers therefrom that his slit extended beyond the reversing layer on each side. He hence infers a minimum thickness of the reversing layer of 524 miles. H. A. N.

3. *Catalogue of Stars observed at the United States Naval Observatory, during the years* 1845–1877, *and prepared for publication by* Professor M. YARNALL, U. S. N., by order of Rear Admiral JOHN RODGERS, U. S. N., Superintendent. Second edition, revised and stereotyped, 280 pp. 4to. Washington, 1878.—The author of this Catalogue of Stars, Professor Yarnall, died on the 27th of February, 1879; he lived to correct the last proof sheets of this work, but not to see the volume in its completed form. This catalogue includes all the work done at the Observatory with the old instruments, and thus, as the author remarks, forms an epoch in the history of the Observatory. It is a work of high intrinsic excellence and is of especial interest as containing the results of the life work of a most accurate, patient and untiring observer.

4. *Astronomical and Meteorological Observations made during the year* 1875 *at the United States Naval Observatory*, Rear Admiral C. H. DAVIS, U. S. N., Superintendent. Published by authority of the Hon. Secretary of the Navy. 4to. Washington, 1878.—In addition to the description of observations made at the Observatory in 1875, which cover 560 pages of the volume, it also contains three Appendixes; one of them is entitled Researches on the Motion of the Moon made at the U. S. Naval Observatory, Part I, by Professor Simon Newcomb. The great work undertaken by Professor Newcomb has as its object the re-investigation of the subject of the Moon's motion, with a view to ascertaining the cause of the deviations of the observations from Hansen's Tables. The part of the work now published contains a reduction and discussions of observations of the moon before 1750, involving the use of much material hitherto but little known. The remaining part, not yet completed, will contain a computation of the action of the planets and the deduction of the mathematical theory of the inequalities of long period in the moon's mean motion.

5. *On the Spectrum of Brorsen's Comet;* by W. H. M. CHRISTIE. —With reference to Professor C. A. Young's Note on the Spectrum of Brorsen's Comet, it may be of interest to mention that observations made at the Royal Observatory, Greenwich, confirm his conclusion as to the coincidence of the brightest band in the comet spectrum with the green band of carbon.

We were not able to examine the comet's spectrum till April 17, as the Great Equatoreal was in the workmen's hands till that date for alterations required to allow of the more convenient use of the spectroscope. On that evening, and again on April 19, the comet's spectrum was repeatedly compared by Mr. Maunder and myself, with the spectrum of alcohol taken in a vacuum tube. The less refrangible edge of the brightest comet-band coincided as exactly as could be determined with the corresponding edge of the green carbon-band at 5,200, but the comet-band was very much wider, extending two-thirds of the way toward F (i. e., about 200 tenth-meters), and covering the carbon-band at 5,200 (about 30 tenth-meters broad) and the two following fainter bands at 5,100 and 5,020. The comparisons were made on April 17 by the help of an occulting bar, and on April 19 with Hilger's bright-line micrometer, illuminated by red light. With the latter, readings for the comet- and carbon-bands respectively, agreed within half a tenth-meter. The half prism spectroscope with a dispersion of 10° from A to H (equivalent to two prisms of 60°) was used on the 13-inch equatoreal. From spectroscopic observations of the carbon compound, printed in the volume of Greenwich Observations, 1875, it appears that the bands in the spectrum of alcohol are identical with those in the spectra of olefiant gas, and of carbon monoxide and dioxide.

A second band was seen in the orange of the comet's spectrum approximately coincident with the carbon band about 5,600.

This band was of about one-fourth the brightness of the principal band.

The results on April 17 were obtained without a knowledge of Professor Young's work, and thus afford an independent confirmation of his conclusion.—*Nature*, May 1.

Royal Observatory, Greenwich, April 21.

V. Miscellaneous Scientific Intelligence.

1. *Notes on Pagosa Springs, Colorado;* by Lieut. C. A. H. McCauley, Third Cavalry, Assistant Engineer, U. S. A. 27 pp. 8vo. Report to the Secretary of War, Feb., 1879; printed by order of Congress.—The Pagosa Springs are situated in the valley of the San Juan river, southern Colorado, on the road from Tierra Amarilla, New Mexico, to the Animas region. The springs have been long known and used by the Ute Indians; they received from them their name *Pah-gosa*—from *pah*, water, and *gosa*, boiling. The group of hot springs occupies an area of about twenty-one acres on the western side of the River. Lieut. McCauley describes nineteen of these, and in addition several cold springs forming an independent group; they are situated in an area of the Cretaceous formation. The largest hot spring has a pear-shaped crater sixty-nine feet long and forty-five feet wide, the depth not determined. An apparent ebullition goes on constantly, but it is gaseous and not due to boiling, the waters rising charged with hydrogen sulphide and carbon dioxide. The temperature of this spring was found to be 141° F., that of the river being 40° F., and the highest air-temperature being 49° (December); the temperature at the exits into the river—the outflow is subterranean—was 127° F. The waters contain, besides the gases, chiefly calcium carbonate and sodium sulphate, with smaller quantities of sodium chloride, sodium, magnesium and lithium carbonates, and potassium sulphate. The deposition of solid matter goes on quite rapidly, stalactites and stalagmites, consisting chiefly of calcium carbonate and sodium sulphate, being formed within the pools.

The temperature of the water in the other springs varied mostly between 135° and 140°, though several of them had temperatures, of only 101°–110°. The cold springs are south of the main spring, on the opposite bank of the river and about half a mile distant; their temperature differs but little from that of the air. Lieut. McCauley's Report contains a series of interesting wood-cuts showing the topographical relations of the country about the springs, and also the details in their structure.

2. *Notes by a Naturalist on the Challenger*, being an account of various observations made during the voyage of H. M. S. "Challenger" around the world in the years 1872–1876, by H. N. Moseley, M.A., F.R.S., Fellow of Exeter College, Oxford, Member of the Scientific Staff of H. M. S. Challenger. 606 pp. 8vo., with a map, two colored plates and numerous woodcuts. London, 1879 (Macmillan & Co.).—These notes make a volume full of facts of interest, popular as well as scientific, relating to the countries and

people visited, icebergs, corals and coral reefs, the habits and nature of some of the stranger animals and plants of the sea and land, and on geological, anthropological and other topics; and they are presented in the direct and lucid style that bespeaks the faithful scientific observer. The author is an able naturalist, and has published many very valuable papers (partly in the Transactions of the Royal Society) as the results of careful work during the cruise and of thorough microscopic investigations since, relating to the structure of *Millepores*, the Alcyonarian relations and structure of *Heliopora cærulea*, the structure of the *Stylasteridae*, on *Corals*, *Actinaria*, *Planariæ*, and other zoological subjects, besides Botanical notes in the Journal of the Linnæan Society.

3. *Report of the National Academy of Sciences.*—At the meeting of the National Academy of Sciences held in Washington, April 15th to 19th, 1879, the following papers were read:

C. S. PEIRCE.—Ghosts in the diffraction spectra; Comparisons of the meter with wave lengths; On the errors of pendulum experiments, and on the method of swinging pendulums proposed by Mr. Faye; On projections of the sphere which preserve the angles.

HENRY DRAPER.—Confirmations by spectrum photographs of the discovery of oxygen in the sun.

E. C. PICKERING.—On the eclipses of Jupiter's satellites; On two new forms of micrometers.

ALFRED M. MAYER.—On a new form of heliostat.

J. E. HILGARD.—Report on the progress of the international bureau of weights and measures; An account of geodetic acts determined by the Coast Survey in relation to the figure of the earth.

SIMON NEWCOMB.—On the recurrence of solar eclipses.

H. A. NEWTON.—On the influence of Jupiter upon bodies passing near that planet.

S. WEIR MITCHELL.—On the relations of neuralgic pains to storms and the earth's magnetism.

C. F. CHANDLER.—On a new polariscopic method for the detection and estimation of dextro-glucose in the presence of cane sugar and inverted sugars.

H. L. ABBOTT.—On the ignition of high tension fuses.

ELIAS LOOMIS.—The winds on Mount Washington compared with the winds near the level of the sea.

E. W. HILGARD.—The loess of the Mississippi, and the Æolian hypothesis.

JOSEPH LECONTE.—The extinct volcanoes about Lake Mono and their relation to our glacial drift.

J. S. NEWBERRY.—On the great silver deposits recently discovered in Colorado, Utah, and Nevada.

G. J. BRUSH.—On a mineral locality in Fairfield County, Connecticut.

A. AGASSIZ.—Report on dredgings in the Caribbean Sea by the Coast Survey steamer Blake, Commander John R. Bartlett, United States Navy.

C. V. RILEY.—On the hybernations and migrations of *Aletia argillacea* (the parent of the cotton-worm).

S. H. SCUDDER.—The Palæozoic cockroaches.

E. D. COPE.—On the extinct species of the Rhinoceros and allied forms of North America.

H. MITCHELL.—On the physical hydrography of the Gulf of Maine.

G. K. GILBERT.—On the stability and instability of drainage lines.

A. GRAHAM BELL.—On vowel theories considered in the light of recent experiments with the phonograph and phonautograph.

F. A. P. BARNARD.—Report of the Committee on Weights, Measures, and Coinage.

Professor William B. Rogers was elected President in place of Joseph Henry, deceased. The following new members were elected: Cleveland Abbe, J. W. Gibbs, W. G. Farlow, H. C. Wood.

APPENDIX.

ART. LXIII.—*Polydactyle Horses, Recent and Extinct;* by Professor O. C. MARSH.

IT is said that the aborigines of this country, when they first saw the horses brought over by the Spaniards, named the new animal "the beast with one finger nail." Certainly, the single hoof on each foot is the most marked characteristic of the modern horse, and one on which some of his most valuable qualities depend. The nearest living allies of the horse are the ass and the zebra, and they possess the same pedal peculiarities.

In addition to each main digit of the ordinary horse, however, the anatomist finds concealed beneath the skin two slender metapodial "splint bones," which are evidently the remnants of two other toes, originally possessed by the ancestors of the horse. It is an interesting fact that these splint bones are sometimes quite fully developed, and may even support extra digits, which are much smaller and shorter than the main foot. As these small hooflets are usually regarded as a serious detriment to the animal, they are generally removed from the colt soon after birth, but in such cases the enlarged splint bones not unfrequently indicate in the adult their former existence.

Numerous cases of extra digits in the horse have been recorded, and in nearly all of them a single lateral hooflet was present on one of the fore legs. In most instances the occurrence was noted chiefly on account of its rarity, and no record was made of the exact position of the extra hoofs with reference to the main digit, nor of the significance of these useless appendages. Since the attention of the writer was called to the subject, a few years since, he has ascertained that these supernumerary digits are much more common in the horse than has been supposed, and in many cases they appear to indicate a reversion to an early ancestral type.

The figures given below represent, (1) the foot of the modern horse in its normal condition, with the splint bones rudimentary; (2) the foot abnormally developed, with one splint bone bearing a small hooflet; and (3) the foot of an extinct three-toed ancestor of the horse. The feet are all from the left side, and the numbers attached indicate the different digits, counting from the inside. The first and fifth, corresponding to the thumb and little finger of the human hand, are wanting in these figures. A specimen similar to that represented in figure 2 is preserved in the Museum of Yale College.

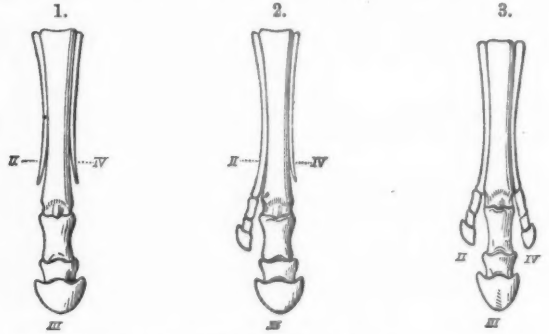


Figure 1.—Fore foot of Horse (*Equus*).
Figure 2.—Fore foot of Horse with extra digit.
Figure 3.—Fore foot of *Hipparion*.

The first recorded instances of extra digits in the horse, known to the writer, are two mentioned by George Simon Winter, in his famous book on Horses, published near the beginning of the last century.* One of the horses referred to and figured in this work was "eight-toed," having a small extra digit on the inside of each foot (p. 134, Plate 21 F.). Winter states that this horse was exhibited in Germany in 1663, and a portrait of it preserved in Cologne. His account was derived from a person who had examined the animal. The other horse described by Winter (page 136, Plate 24), had a small hoof on the inside of each fore foot, and this steed, Winter states, he had not only seen but ridden.

Geoffroy Saint-Hilaire has recorded the fact that he examined a fœtal horse which was polydactyle on the fore feet, the left foot bearing three nearly equal digits, and the right but two.† Owen has described the right fore foot of a horse with a double hoof, the extra digit being on the inner side, answering to

* *De Re Equaria*, Nuremberg, 1703.
† *Annales des Sciences Naturelles*, XI, p. 224. Paris, 1827.

the second digit.* Arloing has figured and described similar specimens.† Leidy has described the right fore leg of a horse with a supernumerary digit on the inner side; and Allen subsequently discussed the same specimen.‡ A number of other instances have been recorded, showing that extra digits are by no means rare in the modern horse.

The most interesting case of this kind examined personally by the writer is the horse represented in figure 4. This animal was on exhibition in New Orleans, in the spring of 1878, and Dr. Stanford E. Chaillé of that city first called the attention of the writer to it, and likewise sent a photograph, from which the cut below was made.

4.

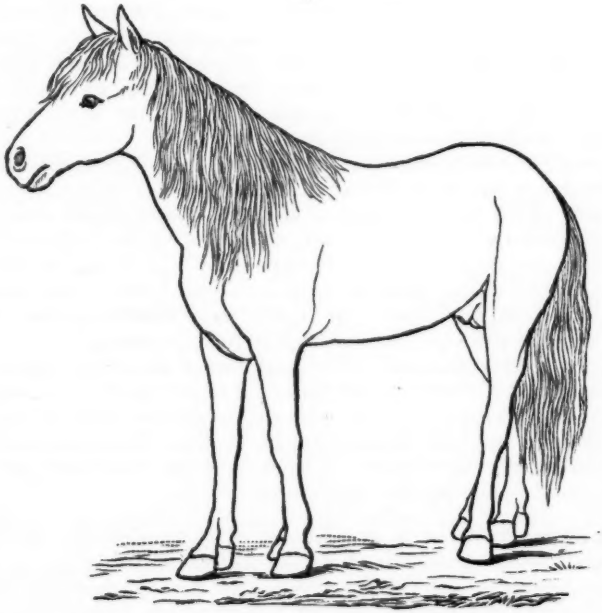


Figure 4.—Outline of horse with extra digit on each foot.

This same horse was subsequently brought to the North, and a few days since was on exhibition in New Haven, Conn., where the writer examined him with some care. The animal is of small size, about ten years old, and is said to have been foaled

* Osteological Catalogue, Museum Royal College of Surgeons, Vol. II, p. 537. London, 1853.

† *Annales des Sciences Naturelles*, VIII, p. 55. 1867.

‡ Proceedings Academy Natural Sciences, Philadelphia. 1871, p. 112, and 1876, p. 92.

in Cuba. He is known among showmen as the "Eight-footed Cuban Horse." With the exception of the extra digits, he is well-formed, and doubtless is capable of considerable speed, although some of the exploits claimed for him may fairly be questioned.

The four main hoofs are of the ordinary form and size. The extra digits are all on the inside, and correspond to the index finger of the human hand. They are less than half the size of the principal toes, and none of them reach the ground. An external examination indicates that the metapodial bone of each extra digit is entire, and at its lower end, at least, is not coössified with the main cannon bone.

There appear to be two phalanges above the coffin bone in each of these digits, which are thus rendered flexible, especially in a fore and aft direction. There was no indication of "interfering" shown on the inner digits themselves, although it is difficult to see how this could be entirely avoided during rapid motion. The splint bone on the outer side of each leg is apparently of the usual shape and size.

Among the instances of recent polydactyle horses, described to the writer by those who have seen them, are two of special interest. One of these was a colt with three toes on one fore foot, and two on the other. The animal recently died in Ohio. Another is a mare, raised in Indiana, and still living, which is said to have three toes on each fore foot, and a small extra digit on each hind foot. In regard to the latter animal, the writer hopes soon to have more definite information.

Besides the instances mentioned above of extra digits in place in the existing horse, there are many cases on record of true monstrosities, as, for example, additional feet or limbs attached to various portions of the body. Such deformities now admit of classification and explanation, but need not be considered in the present discussion.

In reviewing what is now known of extra digits in the feet of the modern horse, the best authenticated instances appear to fall naturally into two groups. The first of these includes digits which are simply cases of reduplication, quite similar to the extra finger occasionally seen in the human hand. Such deformities are apparently a vegetative repetition, the explanation of which has not yet been satisfactorily determined. The second class includes cases where a true digit is formed, the component bones of which are in their normal position, and in proper relation to the rest of the limb. Such instances appear to be clearly due to reversion to some ancestral type. Some digits, which appear at first sight to belong in the first category, may really illustrate the second, but the converse of this is

much less likely to be true. The cases of apparent reversion are of especial interest, and it is important to place on record any information in regard to them, so that they may be compared with extinct allies of the horse.

The cases of extra digits in the horse, so far as at present known, show that these appendages make their appearance more frequently on the fore feet than on the hind feet. This is precisely what a study of the fossil forms of equine mammals would lead us to anticipate.

Another noticeable peculiarity of these extra digits, is their more frequent occurrence on the inside of the main digit, while the outer splint remains rudimentary. This, it must be confessed, is directly opposed to the general law of reduction in the ungulate foot, which, briefly stated, is, that of the five original digits, the first or inner one, first disappears; next the fifth, or outer one; then, the second; and last of all the fourth. The third always remains, as in the horse. It would, therefore, be naturally expected, that when only one additional digit was present, it would be on the outside of the fore foot.

The tendency to interference would seem to be another reason against the retention of the inner digit. Possibly the additional protection which an inside hooflet would receive, might more than counterbalance this influence. Again, the above law is not known to apply to the perissodactyle foot, beyond the first and fifth digits, and if the second digit was originally of greater use than the fourth, and hence was longer retained, an ancestor of the horse may yet be found with the second and third toes alone developed.

In considering these double hoofs of the horse, and with them the well known cleft in the coffin bone of recent and extinct equines, it is important to understand that in no case do they indicate any approach to the true artiodactyle type, as some authors have supposed. The difference between the perissodactyle, or "odd-toed," and artiodactyle, or "even-toed," structure is a profound one, extending to nearly every part of the skeleton, and marking two distinct groups of Ungulates. The number of toes has really nothing to do with the true distinction, and hence the terms in use are especially misleading. The real difference, so far as the feet are concerned, is, that in the perissodactyle type the axis of the limb passes through the middle of the third digit (*Mesaxonia*), while in artiodactyles it is outside of this digit (*Paraxonia*), between it and the fourth.

If, now, we turn back to the early ancestors of the horse for an explanation of the supplementary digits which so often make their appearance, we shall not look in vain, especially in this country. America is the original home of the horse, and

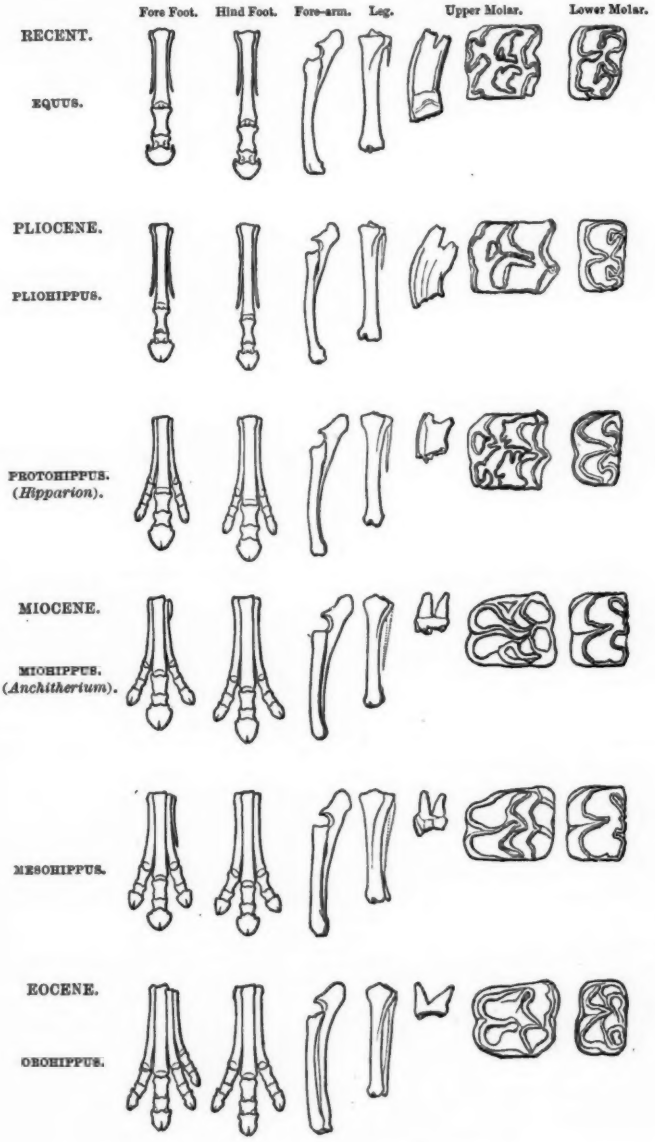
during the whole of Tertiary time, this continent was occupied with equine mammals, of many and various forms. Although all these became extinct before the discovery of this country, their abundant remains mark out the genealogy of the horse in an almost unbroken succession of forms.

If we examine the remains of the oldest representatives of the horse in this country, we shall find that these animals were all polydactyle, and of small size. As the line was continued towards the present era, there was a gradual increase in size, and a diminution in the number of toes, until the present type of horse was produced. In view of the facts mentioned in the preceding pages, it will be profitable to trace the main line of descent in this group, from its first appearance to the present period, and note especially the changes in the number of digits. For this purpose the diagram on page 505 will be instructive, as it records the principal stages in the series, both of the limbs and the teeth as well. This diagram was prepared by the writer for Professor Huxley, who used it first in his New York lectures. The specimens figured are all in the Yale Museum.

The original ancestor of the horse, not as yet discovered, undoubtedly had five toes on each foot. The oldest member of the group now known is the *Eohippus*, which had four well developed toes and the rudiment of another on each fore foot, and three toes behind. This animal was about as large as a fox, and its remains are from the Coryphodon beds, near the base of the Eocene. It is not represented on page 505, as it was found since the diagram was made. In the next higher division of the Eocene, another equine genus, *Orohippus*, makes its appearance. It resembled its predecessor in size, but had only four toes in front and three behind, as shown in the lowest series of the diagram. At the top of the Eocene, a third allied genus has been found (*Epihippus*), which closely resembled *Orohippus* in its digits, but differed in its teeth.

Near the base of the next formation, the Miocene, another equine mammal, *Mesohippus*, occurs. This animal was about as large as a sheep, and had three usable toes and the splint of another, on each fore foot, with but three toes behind, as shown in the diagram. At a somewhat higher horizon, a nearly allied genus, *Miohippus*, has been found, which has the splint bone of the outer or fifth digit reduced to a short remnant. In the Pliocene above, a three toed horse (*Protohippus*) about as large as a donkey was abundant, and still higher up a near ally of the modern horse, with only a single toe on each foot, (*Pliohippus*) makes his appearance. A true *Equus*, as large as the existing horse, appears just above this horizon, and the series is complete.

Yale College, New Haven, May 15th. 1879.



GENEALOGY OF THE HORSE.

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